AN ESSAY ON VISION,

BRIEFLY EXPLAINING THE

FABRIC OF THE EYE,

AND THE

NATURE of VISION:

INTENDED FOR THE SERVICE OF THOSE WHOSE

EYES ARE WEAK OR IMPAIRED:

ENABLING THEM TO FORM AN ACCURATE IDEA OF THE TRUE STATE OF THEIR SIGHT, THE MEANS OF PRESERVING IT, TOGETHER WITH PROPER RULES FOR ASCERTAINING WHEN SPECTACLES ARE NECESSARY, AND HOW TO CHOOSE THEM WITHOUT INJURING THE SIGHT.

By GEORGE ADAMS,

Mathematical Inſtrument Maker to His Majeſty, and Optician to His Royal Highneſs the Prince of Wales.

THE SECOND EDITION.

LONDON:

Printed for the AUTHOR, by R. HINDMARSH,

PRINTER TO HIS ROYAL HIGHNESS THE PRINCE OF WALES,

No. 32, Clerkenwell-Cloſe:

And Sold by the Author, at his Shop, No. 60, FLEET-STREET.

1792.

PREFACE.

THE following Essay is so short, that there is no occasion for a long preface to introduce it to the reader's notice. One of the principal ends of it is to do away a general prejudice in favour of spectacles, namely, that they act as preservers; a prejudice which has caused numbers to use glasses, before they could be of any essential service; who thereby force their eyes into an unnatural state, and bring on a very unpleasant habit. To remedy this evil, the marks are distinctly pointed out, which determine when the use of glasses will be serviceable to the eye. By an attention to the rules here laid down, they will be taught neither to anticipate evil, by a premature use of spectacles; nor, by

by too long a delay, to ſtrain and injure their ſight.

A ſecond end was, to diffuſe more generally a knowledge of the ſubject among the venders of this article, particularly thoſe who live in the country; and this was the more neceſſary, as numerous inſtances are continually occurring to every optician, of thoſe whoſe ſight has been injured by an improper choice of ſpectacles.

The nature of the Eſſay has given me an opportunity of pointing out rules for the preſervation of the ſight, and avoiding what may be hurtful to it. Among the latter, the two principal articles are, the uſe of reading-glaſſes, and opake ſhades to candles; both of which, I have reaſon to think, are extremely prejudicial to the eyes.

As this Eſſay may probably fall into the hands of thoſe who may have no opportunity of conſulting more ſcientific works I have concluded it with an account of ſquinting, the proper methods of aſcertain-
ing

ing the nature of it, and the beſt known remedies for it.

I have here to notice an error, into which, in common with moſt late anatomiſts, I have fallen, with reſpect to the ſtructure of the iris, and the ſituation of the cryſtalline. Mr. O'Hallorah aſſerts, that the iris is not flat, but very convex, and that the inſide of the iris adheres cloſely to the anterior part of the vitreous humour, except where it opens for the lodgment of the cryſtalline, and conſequently that there is no poſterior chamber for the aqueous humour. For a fuller account, I muſt refer the reader to the author's paper.*

I take this opportunity of thanking my friends for ſeveral valuable remarks and corrections, but particularly W. C. Wells, M. D. author of "an Eſſay on ſingle viſion with two eyes," printed for Cadell; a Treatiſe which every one ſhould read, who is deſirous of ſeeing that difficult ſubject put in a clear light.

I have

* Tranſactions of the Royal Iriſh Academy for the year 1788.

I have ſubjoined a liſt of the authors, to whom I am indebted for my information on the ſubjects of this Eſſay.

Ayſcough. Short Account of the Eye. Lond. 1757

Chandler. Treatiſe on the Diſeaſes of the Eye. London, 1780

De la Caille. Leçons Elementaire d'Optique. Paris, 1766

The Fabric of the Eye. London, 1758

Harris. Treatiſe of Optics. London, 1775

Haller. Firſt Lines of Phyſiology. Edinb. 1786

Le Cat. Phyſical Eſſay on the Senſes. Lond. 1750

Martin. Eſſay on Viſual Glaſſes. Lond. 1756

Nicholſon. Introduction to Natural Philoſophy. London, 1787

Porterfield. Treatiſe on the Eye, 2 vols. 8vo. Edinburgh, 1759

Prieſtley. Hiſtory and preſent State of Diſcoveries relating to Viſion. London, 1772

Reid. Inquiry into the Human Mind. London, 1785

Smith. Compleat Treatiſe of Optics. Cambridge, 1738

Thomin. Traité d'Optique. Paris, 1749

Trabaud. Le Mouvement de la Lumiere. Paris, 1753

Warner. Deſcription of the Human Eye. London, 1773

WORKS *lately published by the* AUTHOR *of this* ESSAY.

I. ESSAYS ON THE MICROSCOPE, containing a general, but very ample HISTORY OF INSECTS, describing minutely their various Transformations, singular Habits, and wonderful Œconomy; a full Account of the various Species of Hydræ or Fresh-water Polype, and of the most important Discoveries that have been made by the Microscope; a View of the Organization of Timber, and the Configuration of Salts, when examined with high magnifying Powers; together with a Description of the most improved Microscopes, and the Method of using them. Illustrated with 32 plates, ornamented with an elegant Frontispiece, in one vol. 4to. Price 1l. 6s. in Boards.

II. GEOMETRICAL AND GRAPHICAL ESSAYS, containing a Description of the *Mathematical Instruments* used in Geometry, Levelling, Surveying, &c. Being also a complete Treatise on Practical Geometry, Surveying, both Civil and Military, and Levelling; with a Variety of new Problems illustrative of each Branch. Price 13s. in Boards.

III. AN APPENDIX TO THE GEOMETRICAL AND GRAPHICAL ESSAYS, containing the following Table, by Mr. John Gale, viz. a Table of the Northings, Southings, Eastings, and Westings, to every Degree and fifteenth Minute of the Quadrant, Radius

from 1 to 100, with all the int rmediate Numbers, computed to three Places of Decimals.

IV. ASTRONOMICAL AND GEOGRAPHICAL ESSAYS, containing, 1. A full and comprehenſive View, on a new Plan, of the general Principles of Aſtronomy, with a large Account of the Diſcoveries of Mr. Herſchel. 2. The Uſe of the Celeſtial and Terreſtrial Globes, exemplified in a greater Variety of Problems than are to be found in any other Work: they are arranged under diſtinct Heads, and interſperſed with much curious but relative Information. 3. The Deſcription and Uſe of ſmall Orreries or Planetaria, &c. 4. An Introduction to Practical Aſtronomy, by a Set of eaſy and entertaining Problems. *Second Edition*, 8vo, Price 10s. 6d. in Boards, illuſtrated with 21 Plates.

V. AN ESSAY ON ELECTRICITY; explaining the Principles of that uſeful Science, and deſcribing the Inſtruments contrived either to illuſtrate the Theory, or render the Practice entertaining. To which is now added, *A Letter to the Author from Mr.* JOHN BIRCH, *Surgeon, on the Subject of Medical Electricity*. The fourth Edition, Price 6s. in Boards, with 6 Plates.

ADVERTISEMENT.

PROPOSALS

For PRINTING *by* SUBSCRIPTION,

LECTURES

ON

Natural Philoſophy,

CONSIDERED

In it's preſent State of Improvement.

By GEORGE ADAMS,

AUTHOR *of* ESSAYS *on the* MICROSCOPE, ELECTRICITY, &c.
Mathematical Inſtrument Maker to His Majeſty, and Optician
to His Royal Highneſs the Prince of Wales.

THIS Work is deſigned to deſcribe, in a familiar and eaſy Manner, the principal Phænomena of Nature; to explain their Cauſes, and trace their Relation to, and Dependance on thoſe Cauſes. It is intended to be ſubſervient alſo to other Purpoſes,—to be a Source of uſeful and active Entertainment to young People, while it opens their Minds to enlarged Views of Nature and the Univerſe;—to point out the true Mode of Reaſoning in Philoſophy; thus enabling the Reader to diſtinguiſh what is ſound and ſolid therein, from what is hollow and vain; leading him from a Conſideration of the Works of God, to acknowledge and reverence his Power, Wiſdom, and Goodneſs. The Lectures will be written as far as poſſible in the Manner of Lord Bacon, and will aim (to uſe his Expreſſion) *at aſſiſting the Powers of Man, and extend his Empire over the Works of Creation, by placing the Sciences in ſuch a Light as may excite the Judgment, and promote Invention.*

CONDITIONS.

I. This Work ſhall be neatly printed in Four Octavo Volumes, illuſtrated with a Variety of Cuts.

II. The Price to Subſcribers will be Twenty-four Shillings.

III. No Money is required till the Delivery of the Work, which ſhall be forwarded with all convenient Expedition.

IV. A Liſt of Subſcribers Names will be printed, and delivered with the Work.

Subſcriptions received by the Author, G. ADAMS, No. 60, *Fleet-Street*; J. JOHNSON, *St. Paul's Church-Yard*; G. G. J. and J. ROBINSON, *Pater-noſter-Row*; and J. PHILIPS, *George-Yard*, *Lombard-Street*.

N. B. The Price will be neceſſarily raiſed to Non-Subſcribers.

AN ESSAY ON VISION.

IT is propoſed in this eſſay to inſtruct thoſe whoſe eyes are beginning to fail, how to form a right judgment of the ſtate of their ſight, and of the means of preſerving it; how to determine when the uſe of ſpectacles is neceſſary, and ſo to uſe them, that the ſight may neither be injured by a premature application of glaſſes, nor ſtrained for want of proper aſſiſtance.

But in order to enable the reader to judge for himſelf, and know how to chuſe his ſpectacles, when a choice becomes neceſſary, it will be proper firſt to explain the ſtructure of the eye, and the means by which viſion is performed:

 for

for by underſtanding the principles on which the operations of this wonderful organ depend, he will learn how it may be impaired, and by what aſſiſted. It is alſo preſumed, that it can be no unpleaſing ſpeculation to obtain an idea of the ſecret mechaniſm by which the eye communicates ſo many diverſified and animated perceptions to the ſoul, and by which we are enabled to diſcover, with ſo much caſe and rapidity, every ſurrounding object.

In the ſtructure of the eye we find the moſt evident manifeſtations of exquiſite art and deſign, every part elegantly framed, nicely adjuſted, and commodiouſly placed, to anſwer in the moſt perfect manner every poſſible good purpoſe, and thus evince that it is the work of unerring wiſdom, prompted to action by infinite love.

manifold are the bleſſings we derive from this organ, that the mind of man ſeems almoſt inadequate to the conception, and his pen to the deſcription of them. While it forms our ideas of magnitude and diſtance, it annihilates ſpace, by placing the neareſt and moſt diſtant objects cloſe together. To it we are indebted for the delightful ſenſations that ariſe from the proportion and variety of forms, the harmonious mix-

ture of colours, and the graces of beauty. It enables us to ſeek, to ſee, and to chuſe our food; to go here and there, as the calls of friendſhip, or the occaſions of buſineſs, require; to traverſe the ocean, ranſack the bowels of the earth, viſit diſtant regions, accumulate wealth, and multiply knowledge. Aſſiſted by it, we become acquainted with the works of the Creator, and can trace his wiſdom, his power, and his goodneſs, in the texture of plants, the mechaniſm of animals, and the glories of the heavens.

The value of this ſenſe is heightened, when we conſider the miſeries attendant on the want of it; for among the numerous evils that afflict the human race, there is none more juſtly dreaded, nor more deeply deplored, than a deprivation of ſight. It is to have one of the chief inlets of happineſs cut off, to be ſhut up in perpetual darkneſs, to labour under ten thouſand inconveniences, and to be expoſed to continual dangers. How poignantly this loſs was felt by our great poet, is painfully evident from his own words:

"With the year
Seaſons return; but not to me returns
Day, or the ſweet approach of ev'n or morn,
Or ſight of vernal bloom, or ſummer's roſe,

Or flocks, or herds, or human face divine;
But cloud inſtead, and ever-during dark
Surrounds me, from the chearful rays of men
Cut off, and for the book of knowledge fair,
Preſented with an univerſal blank
Of nature's works, to me expung'd and raz'd,
And wiſdom at one entrance quite ſhut out."

A ſhort Deſcription of the Eye.

In deſcribing the eye, it is natural to conſider, firſt, the external parts, then the internal, or thoſe which are more immediately ſubſervient to the purpoſes of viſion.

The eye, as is well known, is ſituated below the forehead; it is placed in a bony cavity, called the *orbit*; the form is globular, it is compoſed of ſeveral coats and humours, and furniſhed with veſſels properly adapted to it's various functions.

The eye conſiſts of ſeveral *coats* or teguments, which form a *ball* perfectly globular except on the fore part, which is a little more protuberant than the reſt. Within this ball are included three different liquids or tranſparent ſubſtances, called humours.

The

The *orbit* of the eye is of a conical ſhape, but rather irregular in it's dimenſions; it is compoſed of ſeven bones, and lined with fat, which forms a ſoſt bed for the eye to reſt on, and facilitates it's various motions. A conſiderable part of the bottom of the orbit is open for the admiſſion and tranſmiſſion of the nerves, veins, and arteries.

Thoſe prominent arches of hair, which we term the *eyebrows*, defend the eyes from the light when it is too ſtrong, and prevent their being incommoded by any ſubſtances that might ſlide down the forehead, and thence fall into the eyes. That the eyebrows may be more effectually uſeful, and form a more perfect ſcreen, they are furniſhed with muſcles to draw them down, and corrugate them; and when we are walking in a duſty road, or when we are expoſed to a dazzling light, we pull down the eyebrows, and thereby ſhade the eye from the glare, and protect it from the duſt. We may gather from hence, that thoſe ſhades which encompaſs the forehead, and that project about three inches from it, are properly adapted to guard weak eyes from every offenſive glare of light.

The prominency of the eyebrows gives a cha-

racter to the face; and hence Le Brun, in his directions to a painter, with regard to the passions, places in them the principal force of expression. The eyebrows form a deep shade on the canvas, which relieves the other colours and features. A depression of the eyebrow is an indication of concern and grief; whilst an elevation thereof shews that the mind is either affected with joy, or enjoying the serene delights of tranquillity.

The *eyelids*, like two substantial curtains, protect and cover the eyes while we sleep; when we are awake, they diffuse, by their motion, a fluid over the eye, which cleans and polishes it, and thus renders it fitter for transmitting the rays of light.

Each eye is furnished with two lids, the one superior, the other inferior, joining at the two extremities, which are called *canthi*, or angles. Both eyelids are lined with a membrane, which also infolds as much of the globe of the eye as is called the white, and it prevents any dust, or other extraneous particles, from getting behind the eye into the orbit.

That the eyelids may shut with greater exactness, and not fall into wrinkles when they are

elevated

elevated or depreſſed, each edge is ſtiffened by a cartilaginous arch. The eyelaſhes, like two paliſades of ſhort hair, proceed from theſe cartilaginous edges, warning the eye of danger, protecting it from ſtraggling motes, and warding off the wandering fly. They alſo intercept many rays proceeding from objects that are above the axis of viſion, and thereby render the images of other objects more diſtinct and lively: for, as in the camera obſcura, the image is always brighteſt when no rays are allowed to enter, but thoſe which form the picture. The eyelaſhes contribute their ſhare in giving beauty to the face, to ſoften the outlines of the eyelids, and throw a mildneſs on the features.

Both the eyelids are moveable; but the upper one moſtly ſo, the lower one moving but little, being rather obſequious to the motions of the adjacent parts, than moved by any particular forces of it's own. The hairs of the eyelaſhes grow only to a certain length, and never need cutting: the points of the ſuperior one are bent upwards, thoſe of the lower eyelaſh downwards. Thus whenever we can trace things to their final cauſe, we find them always marked with deſign, and can find no circumſtance ſo minute, as to eſcape the attention of the Supreme Being.

From what has been ſaid, we may perceive why the ſight of thoſe, whoſe eyelaſhes are black, is, in general, much ſtronger than thoſe who have them fair or white; the black eyelaſhes are a better ſhade for the eye, and reflect no light from their inner ſide, to weaken and efface the picture on the retina. *Montaltus* gives an account of a young man, whoſe eyelaſhes and eyebrows were of an intenſe white, and his ſight obſcure during the day, but clear at night. This perſon was taken priſoner by the Moors, who dyed his eyelaſhes black, by which his ſight was much ſtrengthened; in courſe of time the dye was waſhed off, and the ſight became weak again. Dr. Ruſſell, in his natural hiſtory of Aleppo, ſays, that it is the cuſtom among the Turkiſh women to black the inſide of their eyelids, not only as an ornament, but as a means of ſtrengthening the ſight. When the eyelaſhes are loſt, a ſymptom which frequently follows a malignant ſmall-pox, the ſight is always conſiderably impaired.

By ſhutting the eyelids partially, we can exclude as much light as we pleaſe, and thus further defend the eyes from too ſtrong a light, which every one's experience proves to be as injurious to them, as more groſs matter. Numerous are

the

the melancholy inſtances on record, which confirm this truth: Xenophon relates, that many of his troops were blinded by the ſtrong reflection of light from the ſnow over which they were obliged to march. Dionyſius, the tyrant of Sicily, among other means which he uſed to gratify his revenge, and ſatiate the cruelty of his temper, was accuſtomed to bring forth his miſerable captives from the deep receſſes of the darkeſt dungeons, into white and well-lighted rooms, that he might blind them by the ſudden tranſition from one extreme to the other. Actuated by principles equally cruel, the Carthaginians cut off the eyelids of Regulus, and then expoſed him to the bright rays of the ſun, by which he was very ſoon blinded.

Theſe facts make it clear that a protuberant eye is not ſo well conſtituted for viſion, as one that is deep ſunk in the head: neither extreme is indeed deſirable, yet undoubtedly, of the two, that which is deep ſet is preferable, as affording the cleareſt ſight, and being leaſt liable to injuries from external accidents.

Thoſe animals which have hard cruſtaceous eyes, as the lobſter, crab, &c. have no eyelids; whereas moſt brute anmals have an additional one,

one, called the *nictitating membrane*, which they draw over their eyes like a curtain, to wipe off whatever incommodes them.

The velocity with which the eyelids move to and fro is ſo great, that it does not in the leaſt impede the ſight. This curious circumſtance may be illuſtrated by the well-known phæno-menon of a burning coal appearing like a ring of fire, when whirled round about with rapidity, in the circumference of a circle. Now it is highly probable, that the ſenſation of the coal, in the ſeveral places of the circle, remains on the mind until it returns again to the ſame place. If, therefore, our eyelids take no longer time to paſs and repaſs upon our eyes, than what the coal of fire takes to go round, the impreſſion made by any object on the eye will ſuffer no ſenſible inter-ruption from this motion.

To prevent the eyelids adhering together, they are ſupplied with a row of ſebaceous glandules, which diſcharge a ſoft liniment, that mixes with, and is waſhed off with the tears.

The *lachrymal gland* is placed in the upper and outer part of the orbit. It is deſigned to furniſh at all times water enough to keep the outer

outer ſurface of the eye moiſt, and thus give the cornea a greater degree of pellucidity. In order that this liquor may be rightly diſpoſed of, we frequently cloſe the eyelids without being conſcious of it.

At the inner corner of the eye, between the eyelids, ſtands a caruncle, whoſe office ſeems to be to keep that corner of the eye from being totally cloſed; ſo that any tears, &c. may flow from under the eyelids when we ſleep, into the *puncta lachrymalia*, which are little holes, one in each eyelid, near the corner, for carrying into the noſe any ſuperfluous tears.

The eye is furniſhed with ſix muſcles, which ſpread their tendons far over the eye; by theſe it can be moved upwards and downwards to either ſide, and in every intermediate direction, and thus view ſurrounding objects without moving the head. To facilitate theſe motions, a great quantity of looſe fat is placed all round the globe of the eye, between it and the orbit. Four of the muſcles are ſtrait, and two oblique; of the ſtrait muſcles, two are ſituated vertically oppoſite one another, and the other two horizontally. Each of the ſix has a proper name, according to it's

it's ſituation and office. I cannot paſs over the muſcles, without taking notice of a ſtriking inſtance of deſign in the wiſe diſpoſition of the parts. It is ſometimes neceſſary to have an oblique motion of the eye, towards the noſe, and there being no room on that ſide for muſcles, a ſmall bone is placed on the ſide of the noſe, with a hole in it, to ſerve as a pulley, through which the tendon of a muſcle paſſes to a convenient inſertion, and thereby ſuch an oblique motion is given to the eye, as would otherwiſe have been impoſſible.

The eyes are placed in the moſt eminent part of the body, near the brain, the ſeat of ſenſation. From their elevated ſituation, our proſpect is enlarged, and the number of objects, taken in at one view, increaſed; we command an ample horizon on earth, and a glorious hemiſphere of the heavens.

Every part of the human frame affords indiſputable proofs of the wiſdom and beneficence of it's Creator, becauſe all are adapted to anſwer in the beſt manner the end for which they were formed. Thus the globular figure of the eye is the moſt commodious that we can form any idea of, the beſt adapted for facilitating the various

motions

motions of the eye, for containing the humours within, and receiving the images from without.

Many are the advantages that are derived from our having two eyes, fome that are known, others that are unknown: for the correfpondence of the double parts in the human frame, and their relation to the two great faculties of the human mind, has not been fufficiently attended to by anatomifts. By having two eyes, the fight is rendered ftronger, and the vifion more perfect; for as each eye looks upon the fame object, a more forcible impreffion is made, and a livelier conception formed by the mind.

The eyes together view an object in a different fituation from what either of them apart would do, and enable us to perceive fmall diftances accurately. Hence we find, that thofe who have loft the fight of one eye, are apt to make miftakes in the diftances of objects, even within arm's length, that are eafily avoided by thofe who fee with both eyes. Such miftakes are principally feen in fnuffing a candle, threading a needle, or in filling a tea-cup. This aptnefs to misjudge diftances and fituations is, however, gradually diminifhed by time and practice.

When

When an object is placed at a moderate diſtance, we ſee more of it by means of the two eyes, than we poſſibly could with one; the right eye ſeeing more of the right ſide, and the left eye more of it's correſponding ſide. Thus by both eyes we ſee in ſome meaſure round an object: and it is this which aſſiſts in giving that bold relievo, which we ſee in nature, and which no painting, how exquiſite ſoever, can attain to. The painter muſt be contented with ſhading on a flat ſurface; but the eyes, in obſerving natural objects, perceive not only the ſhading, but a part of the figure that lies behind thoſe very ſhadings. The perception we have of diſtance with one eye, as was juſt now obſerved, is more uncertain, and more liable to deception than that which we have by both; therefore, if the ſhading and relief be executed in the beſt manner, the picture may have almoſt the ſame appearance to one eye as the objects themſelves would have, but it cannot have the ſame appearance to both. This is not the fault of the artiſt, but an imperfection in the art. To remove theſe defects, the connoiſſeurs in painting look at a picture with one eye through a tube, which excludes the view of all other objects. If the aperture in the tube next the eye be ſmall, we have no means left to

judge

judge of the diſtacce but the light and colour, which are in the painter's power.*

An object ſeen with both eyes, appears a little brighter, or more luminous, than it does when ſeen with one alone, as will be evident by looking alternately with both eyes and with one only: and the difference of brightneſs will be ſtill more manifeſt, if at the ſame time that a part of a flat object, of an uniform colour, is ſeen with both eyes, the light from the adjacent part is excluded from one of them; which may be done, by applying a book to one ſide of the head, ſo that it may reach a little forwarder than the face. But although the difference of brightneſs, in the two caſes, is very perceptible, yet it is not very conſiderable, nor is it eaſy to determine it accurately. Dr. Jurin, by a variety of experiments, concluded, that an object ſeen with both his eyes, appeared only one thirteenth part brighter, than when ſeen with one alone.

Our eyes have an uniform or parallel motion, by which, when one is turned to the right or left, upwards or downwards, or ſtrait forwards, the other always goes along with it in the ſame direction. When both eyes are open, we find them

* Reid's Inquiry into the Human Mind.

them always turned the ſame way, as if both were acted upon by the ſame motive force. This *phænomenon is the more ſingular, as the muſcles which move the two eyes, and the nerves* which ſerve theſe muſcles, are *entirely diſtinct* and unconnected.

To account for and explain the cauſe of this motion, has puzzled the philoſopher, and embarraſſed the anatomiſt: that it orginates from the grand moving principle, or generating cauſe within us, the mind, there can be little doubt; but how the mind operates, to produce this effect, we are altogether ignorant. Some effectual purpoſes are no doubt anſwered by this motion, for nothing is created in vain. One is ſuppoſed to be that of ſeeing objects ſingle that are viewed with both eyes; for there are two pictures formed of every object, one in each eye. Hence, if any of the muſcles of one eye, either from ſpaſm, paralyſis, or any other cauſe, is reſtrained from following the motion of the other, every object will be ſeen double. The ſame effect is produced, if while we are looking at any object, we alter the direction of one of our eyes, by preſſing it aſide with the finger; an experiment frequently made by children, who are generally delighted with any uncommon appearance.

Whatever

Whatever may be the cauſe, the fact is certain, that the object is not multiplied as well as the organ, and appears but one, though ſeen with two eyes: *another inſtance of the ſkill of the contriver of this noble organ, and the exquiſite* art he employed in the formation of it.

Having conſidered the principal external parts of the eye, and ſhewn that they are framed to protect this delicate organ, with a care ſtrictly proportioned to it's curious texture and extenſive uſefulneſs, that it is fortified with ſtrong bones, lodged in a deep receptacle, and guarded with a moveable cover; we now proceed to treat of the internal parts, or thoſe which conſtitute the globe of the eye.

Of the Globe of the Eye.

" If the conſtruction of the univerſe were not ſo evident a proof of the exiſtence of a ſupremely wiſe and benevolent Creator, as to render particular arguments unneceſſary, the ſtructure of the eye might be offered as one, by no means the leaſt; this inſtance, among numberleſs others, demonſtrating that the beſt performances of art are infinitely ſhort of thoſe which are continually produced by the DIVINE MECHANIC.

The globe of the eye, or the organ of fight, may be defined in general as a kind of cafe, confifting of feveral coats, containing three pellucid humours, which are fo adjufted, that the rays proceeding from luminous objects, and admitted at a hole in the fore part of the eye, are brought to a focus upon the back part of it, where they fall upon a foft pulpy fubftance, from whence the mind receives it's intelligence of vifible objects.

It is not to be expected, that any account given of the eye can be altogether accurate; for as it is impoffible to examine all the parts of the eye whilft in a natural and living ftate, fo it is alfo nearly impoffible, when it is taken out of it's focket, to preferve the figure of the parts entire; a circumftance which accounts for the difagreement we find among anatomifts.

Of the Coats of the Eye.

The eye is compofed externally of three coats or teguments, one covering the other, and forming a ball perfectly globular, except at the fore part, which is a little more protuberant than the reft; within this ball are three different fubftances, called humours.

The

The firſt, or outer coat, is called the *ſclerotica*; the ſecond, or middle one, is called the *choroides*; the interior one is named the *retina*.

Sclerotica. Cornea.

The exterior membrane, which incloſes and covers the whole eye, is called the ſclerotica and cornea: it is, however, ſtrictly ſpeaking, but one and the ſame membrane, with different names appropriated to different parts: the hinder and opake part being more generally denominated the ſclerotica, the fore and tranſparent part the cornea.

The *ſclerotica* is hard, elaſtic, of a white colour, reſembling a kind of parchment; the hinder part is very thick and opake, but it grows gradually thinner as it advances towards the part where the white of the eye terminates. The fore part is thinner, and tranſparent; it is alſo more protuberant and convex than the reſt of the eye, appearing like a ſegment of a ſmall ſphere applied to a larger, and is called *cornea* from it's tranſparency. The cornea is thick, ſtrong, and inſenſible; it's tranſparency is neceſſary for the free admiſſion of the light. This membrane is compoſed of ſeveral plates, laid

one over the other, replenifhed with a clear water, and pellucid veffels; thefe plates are more evidently diftinct in the fore than the hinder part. The fclerotica is embraced on it's outfide by fix mufcles, by which the eye may be moved in any direction.

Choroides. Uvea. Iris.

Under the fclerotica is a membrane, known by the name of the *choroides*; it is a foft and tender coat compofed of innumerable veffels; it is concentric to the fclerotica, and adheres clofely to it by a cellular fubftance, and many veffels. This membrane is outwardly of a brown colour, but inwardly of a more ruffet brown, almoft black. Like the fclerotica, it is diftinguifhed by two different names, the fore part being called the *uvea*, while the hinder part retains the name of the *choroides*.

The fore part commences at the place where the cornea begins; it here attaches itfelf more ftrongly to the fclerotica by a cellular fubftance, forming a kind of white narrow circular rim: the choroides feparates at this place from the fclerotica, changes it's direction, turning, or rather folding, directly inwards, towards the axis of the eye, cutting the eye as it were tranf-

verfely:

versely: in the middle of this part is a round hole, called the pupil, or sight of the eye: the pupil is not exactly in the middle of the iris, that is to say, the centers of the pupil and iris do not coincide, the former being a little nearer the nose than the latter.

This part, when it has changed it's direction, is no longer called the choroides; but the anterior surface, which is of different colours, in different subjects, is called the *iris*; the posterior surface is called the *uvea*, from the black colour with which it is painted. The iris has a smooth velvet-like appearance, and seems to consist of small filaments regularly disposed, and directed towards the center of the pupil.

The eye is denominated blue, black, &c. according to the colour of the iris. The more general colours are the hazel and the blue, and very often both these colours are found in the same eye. It has been observed, that in general those, whose hair and complexion are light-coloured, have the iris blue or grey; and on the contrary, those whose hair and complexion are dark, have the iris of a deep brown: whether this occasions any difference in the sense of vision, is not discoverable. Those eyes which are called

black, when narrowly inſpected, are only of a dark hazel colour, appearing black, becauſe they are contraſted with the white of the eye. "The black and the blue are the moſt beautiful colours, and give moſt fire and vivacity of expreſſion to the eye. In black eyes there is more force and impetuoſity; but the blue excel in ſweetneſs and delicacy."

The pupil of the eye has no determinate ſize, being greater or ſmaller, according to the quantity of light that falls upon the eye. When the light is ſtrong, or the viſual object too luminous, we contract the pupil, in order to intercept a part of the light, which would otherwiſe hurt or dazzle our eyes; but when the light is weak, we enlarge the pupil, that a greater quantity may enter the eye, and thus make a ſtronger impreſſion upon it. This aperture dilates alſo for viewing diſtant objects, and becomes narrower for ſuch as are near. The contraction of the pupil is a ſtate of violence, effected by an exertion of the will: the dilatation is a remiſſion of power, or rather an intermiſſion of volition.* The latitude

* Anatomiſts obſerve, that in animals of prey, both beaſts and birds, the pupil is round as in man, which fits them to ſee every way; but in large animals which feed on graſs, the

titude of contraction and dilatation of the pupil is very confiderable; and it is very admirable, that while the pupil changes it's magnitude it preferves it's figure.

Anatomifts are not agreed, whether the iris be compofed of two fets of fibres, the orbicular and radial, or of either. Haller fays, he could never difcover the orbicular fibres, even with a microfcope; the radial feem vifible to the naked eye, and are fufficient to anfwer all the purpofes required in the motion of the iris: when the pupil is contracted the radial fibres are ftrait, when it is dilated they are drawn into ferpentine folds.

In children this aperture is more dilated than in grown perfons. In elderly people it is ftill fmaller than in adults, and has but little motion; hence it is, that thofe who begin to want fpectacles, are obliged to hold the candle between the eye and the paper they read, that the ftrong light of the candle may force their rigid pupils into fuch a ftate of contraction, as will enable them

the pupil is oblong horizontally, for taking in a large circular fpace of ground: the pupil in animals of the cat kind, which climb trees, and want to look upwards and downwards, is oblong vertically.

to ſee diſtinctly. Thoſe who are ſhort-ſighted, have the pupils of their eyes, in general, very large; whereas in thoſe whoſe eyes are perfect, or long-ſighted, they are much ſmaller.

The whole of the choroides is opake, by which means no light is allowed to enter into the eye, but what paſſes through the pupil. To render this opacity more perfect, and the chamber of the eye ſtill darker, the poſterior ſurface of this membrane is covered all over with a black mucus, called the pigmentum nigrum. This pigment is thinneſt upon the concave ſide of the choroides, near the retina, and on the fore ſide of the iris; but is thickeſt on the exterior ſide of the choroides, and the inner ſide of the uvea.

The circular edge of the choroides, at that part where it folds inwards to form the uvea, ſeems to be of a different ſubſtance from the reſt of the membrane, being much harder, more denſe, and of a white colour; it has been called by ſome writers the ciliary circle, becauſe the ligamentum ciliare (of which we ſhall ſoon ſpeak) ariſes from it.

Retina.

Retina.

The third and laſt membrane of the eye is called the retina, becauſe it is *ſpread* like *a net* over the bottom of the eye; others derive the name from the reſemblance of the net which the gladiators called retiarii employed to entangle their antagoniſts. It is the thinneſt and leaſt ſolid of the three coats, a fine expanſion of the medullary part of the optic nerve. The convex ſide of it lines the choroides, the concave ſide covers the ſurface of the vitreous humour, terminating where the choroides folds inwards. It is an eſſential organ of viſion; on it the images of objects are repreſented, and their picture formed. This membrane appears to be black in infants, not ſo black at the age of twenty, of a greyiſh colour about the thirtieth year, and in very old age almoſt white. The retina, however, is always tranſparent and colourleſs: any apparent changes, therefore, of it's colour muſt depend upon alterations of the *pigmentum*, which is ſeen through it.

Optic Nerve.

Behind all the coats is ſituated the optic nerve, which paſſes out of the ſcull, through a ſmall hole

hole in the bottom of the orbit which contains the eye. It enters the orbit a little inflected, of a figure ſomewhat round, but compreſſed, and is inſerted into the globe of the eye, not in the middle, but a little higher and nearer to the noſe; an artery runs through the optic nerve, goes ſtrait through the vitreous humour, and ſpreads itſelf on the membrane that covers the backſide of the cryſtalline.

Monſ. Mariotte has demonſtrated, that our eyes are inſenſible at the place where the optic nerve enters: if, therefore, this nerve had been ſituated in the axis of the eye itſelf, then the middle part of every object would have been inviſible, and where all things contribute to make us ſee beſt, we ſhould not have ſeen at all; but it is wiſely placed by the divine artiſt for this and other advantageous purpoſes, not in the middle, but, as we have already obſerved, a little higher and nearer to the noſe.

Of the Humours of the Eye.

The coats of the eye, which inveſt and ſupport each other, after the manner of an onion, or other bulbous root, include it's humours, by which name are underſtood three ſubſtances, the one a ſolid, the ſecond a ſoft body, and the third truly

truly a liquor. Theſe ſubſtances are of ſuch forms and tranſparency, as not only to tranſmit readily the rays of light, but alſo to give them the poſition beſt adapted for the purpoſes of viſion. They are clear like water, and do not tinge the object with any particular colour.

Aqueous Humour.

The moſt fluid of the three humours is called the aqueous one, filling the great interſtice between the cornea and the pupil, and alſo the ſmall ſpace extending from the uvea to the cryſtalline lens; it is thin and clear like water, though ſomewhat more ſpirituous and viſcuous; it's quantity is ſo conſiderable, that it ſwells out the fore part of the eye into a protuberance very favourable to viſion. The uvea ſwims in this fluid. It covers the fore part of the cryſtalline; that part of this humour which lies before the uvea, communicates with that which is behind, by the hole which forms the pupil of the eye. It is included in a membrane, ſo tender, that it cannot be made viſible, nor preſerved, without the moſt concentrated lixivial fluid.

It has not been clearly aſcertained whence this humour is derived; but it's ſource muſt be plentiful;

tiful; for if the coat containing it be ſo wounded that all the humour runs out, and the eye be kept cloſed for a ſeaſon, the wound will heal, and the fluid be recruited.

The colour and conſiſtence of this humour alters with age; it becomes thicker, cloudy, and leſs tranſparent, as we advance in years, which is one reaſon, among others, why many elderly people do not reap all that benefit from ſpectacles which they might naturally expect.

Cryſtalline.

The ſecond humour of the eye is the *cryſtalline*, which is as tranſparent as the pureſt cryſtal; and though leſs in quantity than the aqueous humour, yet it is of equal weight, being of a more denſe and ſolid nature; in conſiſtency it is ſomewhat like a hard jelly, growing ſofter from the middle outwards. It's form is that of a double convex lens, of unequal convexities, the moſt convex part being received into an equal concavity in the vitreous humour.

The cryſtalline is contained in a kind of caſe, or capſule, the fore part of which is very thick and elaſtic, the hinder part is thinner and ſofter. This

This capſule is ſuſpended in it's place by a muſcle called *ligamentum ciliare*, which, together with the cryſtalline, divides the globe of the eye into two unequal portions; the firſt and ſmaller one contains the aqueous humour, the hinder and larger part the vitreous humour. The cryſtalline has no viſible communication with it's capſule, for as ſoon as this is opened the humour within ſlips clean out.

The cryſtalline is placed ſo, that it's axis correſponds with that of the pupil, and conſequently it is not exactly in a vertical plane dividing the eye into two equal parts; but ſomewhat nearer the noſe. It is formed of concentric plates or ſcales, ſucceeding each other, and theſe ſcales are formed of fibres elegantly figured, and wound up in a ſtupendous manner; theſe are connected by cellular fibres, ſo as to form a tender cellular texture. Between theſe ſcales is a pellucid liquor, which in old age becomes of a yellow colour. The innermoſt ſcales lie cloſer together, and form at laſt a ſort of nucleus, harder than the reſt of the lens. The cryſtalline has no viſible communication with it's capſule, ſo that when this is opened, it readily ſlips out: ſome ſay, that a ſmall quantity of water is effuſed round it. Leeuwenhoeck has computed that there are near

near two thousand laminæ, or scales, in one cryſtalline, and that each of theſe is made up of a ſingle fibre, or fine thread, running this way and that, in ſeveral courſes, and meeting in as many centers, and yet not interfering with, or croſſing each other.

The yellow colour wherewith the cryſtalline is more and more tinged as we advance in years, muſt make all objects appear more and more tinged with that colour: nor does our being inſenſible of any change in the colour of objects, prove to us that their colour continues the ſame; for in order that we ſhould be ſenſible of this change, the tincture muſt not only be conſiderable but it muſt happen on a ſudden, as will be more fully explained hereafter. In the cataract it is opake; the ſeat of this diſorder is in the cryſtalline lens.

Vitreous Humour.

The vitreous is the third humour of the eye; it receives it's name from it's appearance, which is like that of melted glaſs. It is neither ſo hard as the cryſtalline, nor ſo liquid as the aqueous humour; it fills the greateſt part of the eye, extending from the inſertion of the optic nerve to the

the cryſtalline humour. It ſupports the retina, and keeps it at a proper diſtance for receiving and forming diſtinct images of objects.

The vitreous humour is contained in a very thin pellucid membrane, and concave at it's fore part, to receive the cryſtalline; at this place it's membrane divides into two, the one covering the cavity in which the cryſtalline lies, the other paſſing above, and covering the fore part of the cryſtalline, thus forming a kind of ſheath for the cryſtalline. The fabric of the vitreous humour is cellular, the ſubſtance of it being divided. by a very fine tranſparent membrane into cellules, or little membranous compartments, containing a very tranſparent liquor.

Ligamentum Ciliare.

There is ſtill one part to be deſcribed, which, though very delicate and ſmall, is of great importance; it is called the ligamentum ciliare, becauſe it is compoſed of ſmall filaments, or fibres, not unlike the cilia, or eyelaſhes; theſe fibres ariſe from the inſide of the choroides, all round the circular edge, where it joins the uvea; from whence they run upon the fore part of the vitreous humour, at that place where it divides

to

to cover the cryſtalline; thoſe fibres are at ſome diſtance from one another, but the interſtices are filled up with a dark-coloured mucus, giving it the appearance of a black membrane.

Of the Figure repreſenting the Eye.

Figure 1, repreſents a ſection of the eye thro' the middle, by an horizontal plane paſſing through both eyes; the diameter of the figure is about twice the diameter of the human eye.

The outermoſt coat, which is called *ſclerotica*, is repreſented by the ſpace between the two exterior circles B F B; the more globular part, adjoining to the ſclerotica at the points B B repreſented by the ſpace between the two circles at B A B, is the *cornea*.

The next coat under the ſclerotica is a membrane of leſs firmneſs, repreſented by the two innermoſt circles of B F B, and called the *choroides*.

Adjoining to the choroides, at B B, is a flat membrane, called the uvea. a a is the pupil, being a ſmall hole in the uvea, a little nearer the noſe than the middle.

V the

V the *optic nerve;* the fibres of this nerve, after their entrance into the eye, ſpread themſelves over the choroides, forming a thin membrane, called the retina, and is repreſented in the figure by the thick ſhade contiguous to the circle B F B.

E E is the *cryſtalline* humour; it is ſuſpended by a muſcle B b b B, called the *ligamentum ciliare.* This muſcle ariſes behind the uvea at B B, where the ſclerotica and cornea join together at b b; it enters the capſula, and thence ſpreads over a great part of it's anterior ſurface.

The *aqueous* humour occupies the ſpace B A B b C b.

The larger ſpace B b D b B F contains the *vitreous* humour.

The foregoing deſcription, we preſume, will be found ſufficient to give the reader a general idea of the conſtruction of this wonderful organ: for a fuller account we muſt refer him to the writers on anatomy. Enough has been exhibited to ſhew with what art and wiſdom the eye has been conſtructed. "And he muſt be very ignorant of it's ſtructure, or have a very ſtrange

caſt of underſtanding, who can ſeriouſly doubt, whether or not the rays of light and the eye were made for one another, with conſummate wiſdom, and perfect ſkill in optics."

"If we ſhould ſuppoſe an order of beings endued with every human faculty but that of ſight, how incredible would it appear to ſuch beings, accuſtomed only to the ſlow information of touch, that, by the addition of an organ, conſiſting of a ball and ſocket of an inch diameter, they might be enabled, in an inſtant of time, without changing their place, to perceive the diſpoſition of a whole army, the order of a battle, the figure of a magnificent palace, or all the variety of a beautiful landſcape? If a man were, by feeling, to find out the figure of the Peak of Teneriffe, or even of St. Peter's church at Rome, it would be the work of a life-time.

"It would appear ſtill more incredible to ſuch beings as we have ſuppoſed, if they were informed of the diſcoveries which may be made by this little organ, in things far beyond the reach of any other ſenſe. That, by means of it, we can find our way on the pathleſs ocean, traverſe the globe of the earth, determine it's ſize and figure, meaſure

ſure the planetary orbs, and make diſcoveries in the ſphere of the fixed ſtars.

" Would it not appear ſtill more aſtoniſhing to theſe beings, if they ſhould be further informed, that by means of this organ we can perceive the tempers and diſpoſitions, the affections and paſſions, of our fellow-creatures, even when they want moſt to conceal them? that by this organ we can often perceive what is ſtrait and crooked, in the mind as well as the body: that it participates of every mental emotion, the ſofteſt and moſt tender, as well as the moſt violent and tumultuous: that it exhibits theſe emotions with force, and infuſes into the ſoul of the ſpectator the fire and the agitation of that mind in which they originate? To many myſterious things muſt a blind man give credit, if he will believe the relations of thoſe that ſee! his faith muſt exceed that which the poor ſceptic derides as impoſſible, or condemns as abſurd.

" It is not, therefore, without reaſon, that the faculty of ſeeing is looked upon as more noble than the other ſenſes, as having ſomething in it ſuperior to ſenſation, as the ſenſe of the under-

 ſtanding,

ſtanding, the language of intelligence. The evidence of reaſon is called *ſeeing*, not feeling, ſmelling, taſting; nay, we expreſs the manner of the divine knowledge by *ſeeing*, as that kind of knowledge which is moſt perfect in ourſelves."*

* Reid's Inquiry into the Human Mind.

Of

Of the Nature and Properties of Light and of Viſion.

BEFORE we can attain any ſatisfactory knowledge of the nature of viſion, it will be neceſſary to point out ſome of the properties of light. There is no part of the inanimate creation more wonderful and aſtoniſhing than the rays of light, and the phænomena occaſioned by them: the knowledge of theſe properties, and the nature of viſion, is with propriety reckoned as one of the moſt important articles of natural knowledge: it conſtitutes the ſcience of optics, on whoſe utility and excellence it would be needleſs to expatiate, after obſerving, that to this ſcience we owe the invention of thoſe optical machines, which correct the imperfections of ſight, and increaſe it's natural powers; making us acquainted with beings whoſe minuteneſs renders them imperceptible, and bringing to hand objects, whoſe remote ſituation affords to the eye either no information, or ſuch as is imperfect and erroneous.

The rays of light are of ſuch extreme minuteneſs, as to pervade with facility bodies of the

closest texture, and greatest density: their velocity is so great, that if the particles of light were equal in mass to the one millionth part of a grain of sand, we should no more be able to endure their impulse, than that of sand shot point-blank from a cannon. The rays cross each other in all directions, without the least disturbance; for through a hole, not exceeding one-hundredth part of an inch in diameter, we can easily view the objects, which occupy almost an entire hemisphere; the light proceeding from all these objects must, therefore, pass at the same time through the hole in a great variety of directions, before they arrive at the eye, and that without interfering with each other, and preventing the sight of the objects. How exquisitely minute must these particles be, that myriads of them can move promiscuously all manner of ways, without impinging one another. That light moves with greater velocity than sound, is known to every one; because the flash of a gun, fired at a considerable distance, will be seen some time before the sound is heard; but sound is known to move at the rate of 1142 feet in a second of time. It was reserved, however, to modern astronomers, to discover with exactness the velocity of light; and from their observations it appears, that it passes through about one hundred and seventy thousand

geogra-

geographical miles in a ſecond of our time. Milton invokes light in the following ſublime manner.

"Hail, holy light, offspring of heav'n firſt-born;
Or of th' eternal co-eternal beam
May I expreſs thee unblam'd? ſince God is light,
And never but in unapproached light
Dwelt from eternity, dwelt them in thee,
Bright effluence of bright eſſence increate.
Or hear'ſt thou rather pure etherial ſtream,
Whoſe fountain who ſhall tell? before the ſun,
Before the heavens thou wert, and at the voice
Of God, as with a mantle, didſt inveſt
The riſing world of waters, dark and deep;
Won from the void and formleſs infinite."

Whatever is ſeen or beheld by the eye, is by opticians called an *object*.

They conſider every object as made up of a vaſt number of minute points, and that each of theſe points, by an unknown power, ſends forth or reflects rays of light in all directions, and is thus the center of a ſphere of light, extending indefinitely on all ſides.

To render this plainer, let us ſuppoſe one point of an object to be ſingled out from the reſt, and repreſented by P, fig. 4, then the lines proceeding from it may be conſidered as the rays of light. Now it is evident, by inſpecting the figure, that in whatever poſition the eye be placed, whether at A, at B, or C, &c. the point will be viſible, rays being ſent from it to every part.

It appears further, from all experiments that have hitherto been made, that the rays of light proceed from every point of an object in ſtrait lines; but that they are refracted or bent out of this rectilinear courſe, whenever the denſity of the medium, through which they paſs, is increaſed or diminiſhed.

By a *medium*, in the language of opticians, is meant any tranſparent ſubſtance, ſolid or fluid, through which light paſſes.

One medium is ſaid to be more denſe than another, when it contains more matter in the ſame bulk or ſize: thus glaſs is more denſe than water, water is more denſe than air.

Light is more refracted, or bent, in paſſing from air into glaſs, than from air into water; or,

or, in other words, the denſer the medium is, the more the rays are bent, and approach a perpendicular let fall from it's ſurface. An increaſe of denſity is not the only circumſtance which augments the refracting power of bodies, a ſimilar effect is produced by an increaſe of inflammability.

The direction with which the rays of light fall on any medium, is as much to be conſidered as it's denſity.

For if a ray falls perpendicularly on the ſurface of any medium, it is not bent, but goes on in the ſame direction in which it entered, the refraction only taking place when the rays fall obliquely, and is ſo much greater, as the incidence is more oblique, and the medium is more denſe. Thus, for example, the rays are more bent in paſſing from air into glaſs, than from air into water.

The following pleaſing and eaſy experiment will give the reader a clear idea of what is meant by the refraction of the rays of light; a wonderful property, to which we are indebted for all the advantages of viſion, and the aſſiſtance received from glaſſes.

Experiment.

Experiment. Into any ſhallow veſſel (a baſon) put a ſhilling, and retire to ſuch a diſtance as that you can juſt ſee the farther edge of the ſhilling, but no more: let the veſſel, the ſhilling, and your eye, remain in the ſame ſituation, while an aſſiſtant fills up the veſſel with water, and the whole ſhilling will then become viſible.

Thus the eye E, fig. 2, can ſee no part of the piece of money b D in an empty baſon B; but pour water into the baſon up to c, and the whole piece will be ſeen; becauſe the ray A c D, which was ſtrait before, is now bent into the form A c B.

For the ſame reaſon, a ſtrait ſtick put partly into water appears bent.

Every ray of light carries with it an image of that point from which it proceeded. If, therefore, all the rays coming from any point, can be united in the ſame order in which they were emitted, there will be a perfect repreſentation or image of the object, at the place where they are thus orderly united.

The whole apparatus of the eye is deſigned to produce this orderly union of the rays. The ſame purpoſe

purpoſe is alſo effected by means of convex lenſes.

It is by the refraction of the rays of light, that this union is brought about. We have already obſerved, that if a ray of light falls perpendicularly upon the ſurface of any medium, it will continue to go on in a ſtrait line, in the ſame direction it was moving in before; but if it falls obliquely upon the ſurface of the ſecond medium, it will be refracted at the point of incidence, ſo as to be bent towards the perpendicular, when it paſſes out of a thinner into a more denſe one; and from the perpendicular, when it paſſes out of a denſer into a thinner medium.

The parallel rays, fig. 3, a b c d e f g, falling obliquely on the ſurface A D B of a double convex lens, are refracted or bent inward, by paſſing through the lens, and meet in a focus, or point, at C, which is the center of the lens's convexity.

The middle ray d D falling perpendicularly on the ſurface of the lens at D, ſuffers no refraction in paſſing through it.

By this means, if a number of rays, proceeding from any one point, fall on a convex ſpherical ſurface

ſurface of glaſs, they will be bent or refracted, ſo as to be nearly united in a point behind the glaſs, and there form a repreſentation of the original point.

Hence, when the rays which come from all the points of an object, meet again in as many points, after they have been re-united by refraction, they will at theſe poins of re-union form a picture of the object upon any white body on which they fall.

An eaſy and very ſimple experiment will enable the reader to comprehend this part, better than any explanation in words.

Experiment. Let B B, fig. 5, repreſent a darkened room, or box, into which no light is admitted but what comes through a glaſs lens at O. Let D E F be objects without doors.

The rays of light coming from the objects will be turned out of their courſe by the refractive power of the lens, and be made to unite at the focus of the lens.

If, therefore, a piece of white paper* be held at

* The picture appears beſt upon white, becauſe white bodies reflect light of all the different colours more copiouſly, and more equably than bodies of any other colour.

at the focus, the pictures of the objects will be fairly and orderly reprefented on the paper, in their natural colours and proportions, but in an inverted fituation.

Every phyfical point of the objects fends forth it's cone of rays, which, by means of the lens, are made to unite orderly at CH, and being there reflected by the paper, the image of the whole object is diftinct and vifible, like a picture drawn upon canvas, but much more lively and diftinct than the beft finifhed drawing of the fineft artift.

If the paper be removed nearer to, or farther from the lens, the picture will be confufed; be-caufe the rays proceeding from the next adjacent points of the objects, begin to interfere, and mix together.

The diftinctnefs of the picture depends upon the feparation of the rays belonging to every point of the object, upon their reception by the paper.

If the paper be removed farther and farther from the focus, the picture will become more and more indiftinct, and at length totally vanifh, no one part being diftinguifhable from the reft, be-
caufe

cauſe the rays from remote parts are mixed with the others. It is for the ſame reaſon, that the room muſt be dark, otherwiſe the foreign light, by mixing with the pencils that form the picture, will ſo weaken it, that at laſt, as the light grows ſtronger, it will become inſenſible, being effaced by the adventitious rays.

The cauſe of the inverſion of the image is evident from a bare inſpection of the figure; and it is plain, that this inverſion is not to be attributed to the lens: for if the lens be removed, and the light be admitted into the room by a hole of about one-tenth of an inch diameter, we ſhall have, on the paper, an inverted, though imperfect, picture of the objects without, in the ſame manner as when the light comes through the lens.

In both caſes the ſeveral pencils of rays neceſſarily croſs each other; but without the lens, the picture will be faint and confuſed: it is faint, becauſe there are but few rays for forming each point of the image; whereas the lens collected many together in one point, and thus rendered the image ſtronger; the picture is confuſed, becauſe the rays that proceed from adjacent objects interfere, and mingle together.

By

By the lens, a great number of rays are united in the ſame ſenſible point, and this is the principal uſe of it; and the image is brighter, in proportion as there are more rays united; and more diſtinct, in proportion as the order in which they proceed is better preſerved in their union.

Of Viſion.

The foregoing repreſentation of objects upon a ſheet of paper, by means of a lens placed at a hole in a window-ſhutter, is exceedingly ſimilar to what happens to our eyes when we view objects. For viſion, ſo far as our eyes are concerned, conſiſts in nothing but ſuch a refraction of the rays of light by the tranſparent ſkins and humours of the eye as will form a diſtinct picture of the object on the retina. For the ſtructure of the eye plainly indicates, that in order to attain diſtinct viſion, it is neceſſary that a certain quantity of rays from every viſible point of an object ſhould be united at the bottom of the eye, and that the points of union of the rays of the different pencils ſhould be as diſtinct and ſeparate as poſſible.

The eye is admirably contrived for effecting theſe purpoſes: all the rays coming from any viſible point of an object, that can enter the pupil,

pupil, are united closely together upon the retina, and thereby make a much more powerful and stronger impression than a single ray alone could do; to answer this purpose, the retina is placed at a proper distance behind the refracting surfaces, and each pencil of rays is refracted orderly into distinct focuses, that the whole object may be distinctly seen at the same instant.

These effects are owing to the refraction of the rays of light; for if these rays were not so refracted, very few of them would strike upon the least sensible point of the visionary nerve, and the rays from different objects, or from different parts of the same objects, would strike at the same place at once, and thus create an indistinctness equal to blindness.

When the light is weak or strong, the pupil is accordingly enlarged or contracted, for the admission of more or fewer rays, that the impressions on the retina may be rendered suitable to the respective cases.

As the crystalline humour is densest in the middle, it is highly propable that it is not equally refractive. This difference in density of the constituent parts of the crystalline is admirably contrived for correcting the aberration from it's figure,

figure, as well as that of the cornea. The more remote rays of each pencil, by paſſing through a medium, gradually diminiſhing in denſity from the middle towards the extremes, have their focuſes gradually lengthened, which correct the aberrations of the figure, that ſo they may unite nearer together. The concave figure of the retina is ſomewhat ſerviceable for the ſame purpoſe.

It is by no means eaſy to determine with accuracy the meaſure of refraction of the different humours of the eye; from ſuch experiments as could be made, it has been found that the refractive powers of the aqueous and vitreous humours are much the ſame with common water, and that of the cryſtalline a little greater.

The cornea and aqueous humour being ſuppoſed to have the ſame refractive powers, all three may be conſidered as one denſe medium, whoſe refractive ſurface is the cornea; and the cryſtalline humour may be conſidered as a convex lens, placed in a given poſition, within the ſaid medium. Whence the humours of the eye all together make a kind of compound lens, whoſe effect in refracting rays having a given focus of incidence, is eaſily found by the laws of optics.

We ſhall now endeavour to explain the action of the rays of light upon the eye, by a figure. Let PQR, fig. 6, be an object; then the pencils of light BPB, BQB, BRB, from the points PQR, are firſt refracted by the cornea, ſo as to belong to the focuſes a b c, behind the eye; then by the anterior ſurface of the cryſtalline humour, they are again refracted towards the focuſes h i k, nearer to the eye than before; and laſtly, in going out of the cryſtalline into the vitreous humour, they are again refracted, ſo as to unite in the points p q r. In like manner, the pencils of rays coming to the cornea from every phyſical point of the object PQR, are, by the different refracting ſurfaces of the eye, brought orderly to unite upon the retina, and there form, as it were, an image pqr of the object, but in an inverted poſition; the upper part of the object being painted upon the lower part of the retina, the right ſide of the object upon the left ſide of the retina, and ſo of other parts. Thus the cavity of the eye is a kind of *camera obſcura*, the cornea and cryſtalline making a ſort of compound lens, whoſe aperture is limited by the breadth a a of the pupil. And that the parts of the eye are adapted to produce ſuch an image, may be proved by experiment: for if the tunica ſclerotica be taken away from the back of an eye, newly

newly taken out of the head of any animal, and this eye be placed in a hole made in the window-ſhutter of a dark room, ſo that the bottom of the eye be towards you, a beautiful, but inverted, picture of external objects will be exhibited, painted in the moſt lively colours.

If the humours of the eye, by age, or any other cauſe, ſhrink and decay, the cornea and cryſtalline grow flatter than before; and the rays not being ſufficiently bent, arrive at the retina before they are united in their focus, and meet in ſome place behind it, and therefore form an imperfect picture at the bottom of the eye, and exhibit the object in a confuſed and indiſtinct manner: this defect, of which we ſhall treat more particularly hereafter, is remedied by ſpectacles with convex glaſſes, which, by increaſing the refraction of the rays of light, cauſe them to converge more, and thus convene diſtinctly at the bottom of the eye.

On the other hand, if the cornea and cryſtalline be too convex, the rays unite before their arrival at the retina, and the image thereon is of courſe indiſtinct: this defect, like the preceding one, may be remedied by the uſe of glaſſes, though of a contrary figure, for here they muſt

be concave, inſtead of convex; a lens, of a proper concavity, placed before the eye, will make the rays diverge ſo much more than they do in their natural ſtate, as will cauſe them to meet at the retina.

Of the Artificial Eye.

If the eye of an animal be taken out, and the ſkin and fat be carefully ſtripped off from the back part of it, till only the thin membrane which is called the retina, remains to terminate it behind, and any object be placed before the front of the eye, the picture of that object will be ſeen figured as with a pencil on the retina. There are thouſands of experiments which prove that this is the mechanical effect of viſion; but none of them which render it ſo evident as this with the eye of an animal: an eye of an ox newly killed, ſhews it happily, and with very little trouble.

The optical effects of viſion may be very pleaſingly and ſatisfactorily illuſtrated by the inſtrument repreſented at fig. 7, which is called an *artificial eye*.

At the end E there is a piece of glaſs placed, on

on which the form of the eye is painted, a part being left transparent, to represent the pupil; within the globe are inserted three lenses, of different convexities, either of which may be brought opposite to the hole, or pupil; one of these is to answer for the natural state of the eye; the other being less convex, is to shew the state of the eye when flattened by age; the third, more convex than the first, to represent the condition of the short-sighted: at the opposite end A of the globe is a greyed or semi-transparent piece of glass, to represent the retina.

At the front are two lenses, fitted into frames, and moveable by the handle B, one concave, C, the other convex, D, which may be occasionally placed before the eye, to shew how the imperfect states of it are remedied.

If the artificial eye be turned towards any bright object, at a moderate distance, and the lens for the natural sight be brought before the pupil, a lively and distinct, though inverted, picture of the object will be exhibited on the greyed glass. If you take the eye in your hand, you will see a bright vivid image of the window on the greyed glass.

If either of the other lenſes be placed oppoſite the pupil, the picture becomes confuſed; ſhewing, that when the eye has it's due form and figure it has no occaſion for lenſes.

To repreſent a *long-ſighted eye*, bring the glaſs which is leſs convex than the firſt, to coincide with the pupil, and you will find the image very imperfect on the greyed glaſs; but by applying the convex lens, which will cauſe the rays to converge, you will obtain a perfect image of the object. Now remove the glaſs that is behind the pupil, and bring forward in it's place the lens which is more convex, this will repreſent the cornea of *a ſhort-ſighted eye*, as well as it's effect in forming the image ſhort of the retina, and if you hold it up towards the window, you will find that no image of the window is formed, nor can any object at a diſtance have it's image formed with diſtinctneſs in this caſe; but put the concave glaſs before it, and this by rendering the rays leſs convergent will make the rays unite at the retina, and form as perfect an image as before.

Of the inverted Poſition of the Image.

If viſion be owing to the picture on the retina, it

it may be aſked, why the object appears in it's natural *upright poſition?* how, when nature draws the picture the wrong way, her errors are ſo readily corrected?

If it were as eaſy a taſk to give a ſatisfactory explanation of this abſtruſe queſtion, as it is to ſtart objections to every ſyſtem hitherto ſuggeſted, to account for the operations of the mind on the body, and the body on the mind, it would have been explained long ago.*

The difficulty would be ſtill greater, if it was the picture we ſaw, and not the object; but the picture *is not ſeen at all*, the eye can ſee no part of itſelf; the picture is the inſtrument, by means of which the object is perceived; but it is not perceived itſelf, the inſtrument neither perceives, compares, nor judges; theſe are powers peculiar to that pſycological unity which we call the *mind*.

It is abſolutely neceſſary, in conſidering this ſubject, to diſtinguiſh between the organ of perception,

* See, on this ſubject, Reid on the Mind, Potterfield on the Eye, Hartley on Man, Bonnet's Eſſai Analytique ſur l'Ame, Berkeley on Viſion, &c. &c.

ception, and the *being* that perceives. A man cannot ſee the ſatellites of Jupiter, unleſs aſſiſted by a teleſcope: does he therefore conclude from this, that it is the teleſcope that ſees thoſe ſatellites? By no means; the concluſion would be abſurd: nor would it be leſs abſurd, to conclude that it is the eye that ſees: the eye is a natural organ of ſight, but the natural organ ſees as little as the artificial.

Our ſenſes are inſtruments, ſo framed by the Author of our being, that they correſpond with, or have a determined relation to, thoſe qualities in objects which they are to manifeſt to us. It is thus with the eye; it is an inſtrument moſt admirably contrived for manifeſting viſible objects to the mind; for this purpoſe, it refracts the rays of light, and forms a picture upon the retina; but it neither ſees the object, nor the picture. The eye will refract the rays of light, and form the picture, after it is taken out of the head, but no viſion enſues. Even, when it is in it's proper place, and perfectly ſound, an obſtruction in the optic nerve takes away viſion, though the eye has performed all it's functions.

We know, indeed, how the eye forms a picture of viſible objects on the retina; but how this picture

picture makes us see objects, we know not: and if experiment had not informed us that such a picture was necessary, we should have been entirely ignorant of it. The seat of sensation, wherever it is placed, does not appear to be passive in receiving images; the images are the occasion of it's re-action, and directing a ray from itself towards every object it perceives, and this action and re-action are reciprocal. Hence we often see objects when the eye is turned from them, and often do not see the object on which the eye is turned, if the attention be otherwise engaged.

The pictures upon the retina are, however, a mean of vision; for such as the picture is, or such as the action of the rays of light is on the retina, such is the appearance of the object in colour and figure, distinctness or indistinctness, brightness or faintness; but as we are totally ignorant of the mechanism of the mind, or of the organization of the mental eye, we cannot say how this effect operates, and can only conclude, that the natural eye is an instrument of vision.

It appears very clear from Dr. Darwin's experiments, that the retina is often in an active state, and that upon the activity of this organ many

many of the phænomena of viſion depend; an impreſſion on the retina being firſt made by an active power, which produces a conformable change and re-action, that paſſes directly to the ſenſorium, occaſioning, though in an unknown manner, the perception of objects.

On a ſubject, therefore, confeſſedly ſo obſcure, and which is perhaps beyond the limits of human conception in it's preſent ſtate, every explanation muſt be imperfect, every illuſtration inadequate. Among the various attempts of human ſagacity, to ſhew why an *inverted image* is the mean of exhibiting objects to the mind in an upright poſition, the following is perhaps one of the leaſt imperfect.

Every point of an object is ſeen in the direction of a right line, paſſing from the picture of that point on the retina, through the center of the eye, to the object point; and, therefore, ſuch points indicate to the mind the exiſtence of the object point, and it's true ſituation; and of courſe, that the object, whoſe picture is loweſt on the retina, muſt be ſeen in the higheſt direction from the eye; and that object, whoſe picture is on the right of the retina, muſt be ſeen on the left: ſo that by a natural law of our conſtitution,

we

we ſee objects erect by inverted images, and if the pictures had been erect on the retina, we ſhould have ſeen the object inverted.*

But ſuppoſing the preceding illuſtration to be the true one, and quite ſatisfactory, many difficulties ſtill remain, to perplex the philoſopher, and embarraſs the anatomiſt. There are parts of the eye which aſſiſt in perfecting the organ of viſion, whoſe nature and functions are among the deſiderata of ſcience. We are ignorant of the office of the optic nerve, or in what manner it performs that office. That it has ſome part in the faculty of ſeeing, is evident; becauſe in an amauroſis, which is ſaid to be a diſorder of the optic nerve, the pictures on the retina are clear and diſtinct, and yet there is no viſion.

We know ſtill leſs of the uſe and functions of the choroid membrane; it is neceſſary, however, to viſion; for it is well known, that a picture upon that part of the retina where it is not covered with the choroid, namely, at the entrance of the optic nerve, produces no more viſion than a picture upon the hand.† There are, therefore, other

* Reid on the Human Mind.

† This is not concluſive, for where there is no choroid, there

other material organs, whoſe operations are neceſſary to ſeeing, even after the pictures upon the retina are formed; whenever we become acquainted with the uſe of theſe parts, more links of the chain will be brought into our view, and we ſhall better comprehend this wonderful inſtrument.

Having had occaſion to mention that there is no viſion produced by that part of the retina which is not covered by the choroid membrane, it will be proper to illuſtrate this circumſtance more fully, and ſhew in what manner this fact has been aſcertained, the diſcovery of which occaſioned a long controverſy concerning the proper ſeat of viſion.

Experiment. Fix three black patches, A, B, C, upon a white wall, at the height of the eye, A being to the left, and C to the right: place yourſelf facing theſe patches, ſhut the right eye, and direct the left towards the patch C, you will then ſee both A and C, but the middle patch B will diſappear. Or if the left eye be ſhut, and the right

there is no retina, the optic nerve being not yet expanded into that membrane. If the choroid was taken away from behind the retina, there is reaſon to believe that viſion would ſtill take place.

right directed towards A, you will ſtill ſee both A and C, but B will diſappear. If the eye be directed towards B, both B and A will be ſeen, and not C; for which ever of the patches is directly oppoſite to the optic nerve vaniſhes. This experiment is rather difficult at firſt, but becomes eaſy by a little practice. In our uſual intercourſe with common objects, we are not ſenſible of this defect, becauſe we turn the viſual parts of the eye with ſo much rapidity upon the inviſible part of the object, that the loſs, without peculiar attention, is imperceptible; this loſs, however, in one eye, is remedied by the uſe of both, as the part of the object that is not ſeen by one, will be diſtinctly perceived by the other. This defect of ſight, though common to every human eye, was never known, until it was diſcovered by the ſagacity of Monſ. Mariotte in the laſt century.

Of the Extent or Limits of Viſion.

We ſhall now proceed to conſider further the nature, properties, and extent of power of the eyes. As in a dark chamber, a very ſlender beam of light is viſible; ſo in all caſes when the ſurrounding medium is very dark, objects are ſeen by ſmall quantities of light. Hence, when the medium

medium round the eye is dark, a ſmall quantity of light will ſuffice for viſion, the eye being, by the excluſion of the adventitious light, rendered ſenſible to the moſt delicate impreſſions.

The extent, therefore, of our ſight is increaſed or diminiſhed, in proportion to the quantity of light that ſurrounds us, ſuppoſing the illumination of the object to remain the ſame. Hence it has been calculated, that if the ſame object, which during the day we ſee at the diſtance of 3436 times it's diameter, were equally illuminated during the night, it would be viſible at 100 times greater diſtance.

Thus in a dark night the feeble light of a candle may be ſeen at a great diſtance; and the fixed ſtars, though they have no ſenſible diameter, are viſible, and the darker the night, the more of them are ſeen. A certain quantity of light is, however, neceſſary, even in this caſe, for viſion; for the impreſſions of light from the ſatellites of Jupiter and Saturn, are too feeble to be perceived without the aſſiſtance of a teleſcope.

At the approach of day, and as the twilight increaſes, the eye begins to be enlightened by the reflection of the atmoſphere, the ſtars grow fainter,

fainter, and in proportion as the light increaſes, gradually diſappear, firſt thoſe of the leaſt, and at laſt thoſe of the largeſt magnitude. As the day advances, the moon herſelf loſes of her luſtre, till at length her light is overpowered, and ſhe is no longer ſeen. In the ſame manner, ſmall particles are ſeen floating in a beam of light let into a darkened room, but as ſoon as the room is enlightened, thoſe particles diſappear.

One of the reaſons why we are often unable to diſtinguiſh diſtant objects, is the profuſion of rays reflected from intermediate objects, which, by their brilliancy, prevent us from perceiving the fainter rays that proceed from thoſe which are more diſtant, ſo that when the objects are very remote, their picture on the retina is eaſily obliterated, by the vigorous and lively impreſſions made by thoſe that are nearer. But when the intermediate ones emit a feeble light, when compared to that which proceeds from the more remote ones, theſe will form a diſtinct picture on the retina, and become perfectly viſible.

The extent of viſion is not only limited by the light of the ambient medium, which enters the eye with the pencils of light that proceed from ſurrounding

ſurrounding objects; but it is further impeded by the heterogeneous particles that are conſtantly floating in the air: theſe, by their opacity and reflective power, form a kind of veil, that obſcures the viſion of remote objects; and the more the medium is loaded with theſe particles, and the more remote the object is from the ſpectator, the more obſcure and indiſtinct it will appear, and the limits of viſion be more confined.

The exhalations which continually riſe from the earth, augment this obſcurity, and render the air leſs tranſparent, eſpecially near the earth; the celeſtial bodies generally, therefore, appear more obſcure when near the horizon, than when they are at a greater elevation; becauſe, in the firſt caſe, they are ſeen through that part of the atmoſphere which is contiguous to the ſurface of the earth; but in the latter, through a part which is at a greater diſtance.

Every one knows, that objects at a given diſtance are more diſtinctly ſeen, and are viſible at a greater diſtance in clear, than in foggy weather. Thus early in a clear morning, and when the air is free from vapours, and not much enlightened, a hill or a head-land is viſible at a great diſtance; but as the day advances, the land becomes

becomes more obſcure, till at length, by the great opacity of the intervening vapour, and the light reflected by it to the eye, the object becomes leſs and leſs perceptible, and at laſt totally diſappears. Hills, and other high lands, are ſeen more diſtinctly in the morning, partly from this circumſtance, that by their elevation they are more illuminated than the parts intervening between them and the ſpectator.

But the obſcurity ariſing from the exhalations is not the leaſt part of the inconvenience they occaſion; the riſing exhalations have a kind of undulating motion, like that of ſmoke or ſteam, ſo that objects ſeen through them appear to have a tremulous or dancing motion, which is ſenſible even to the naked eye: if diſtant objects be viewed on a hot ſummer's day, this effect is ſo ſenſible in teleſcopes, as to render them entirely uſeleſs for terreſtrial objects, when they augment apparent magnitude more than eighty times.

From this want of tranſparency in the atmoſphere, ariſes that gradual diminution in the light of objects, which painters call the aerial perſpective, by which they endeavour to give that degradation of colour, and indiſtinctneſs of

outlines, peculiar to objects at a diſtance: for if the air were perfectly tranſparent, an object would be equally luminous at all diſtances, becauſe the viſible area and the denſity of light decreaſe in the ſame proportion.

Another cauſe which limits the extent of viſion, and for the removal of which optical inſtruments are more particularly adapted, is their ſmallneſs in proportion to their diſtances: for excepting in the caſe of luminous objects ſeen in the dark, it is neceſſary that an image on the retina ſhould have ſome determinate magnitude, in order to become perceptible; thus a houſe may be ſeen at a conſiderable diſtance, but we muſt approach nearer before the windows are diſcernible, and nearer ſtill to diſtinguiſh the bricks.

It is not eaſy to determine with accuracy the quantity of the *minimum viſibile*, or the angle that is ſubtended by the ſmalleſt viſible object. Mr. Harris has inferred, from ſeveral experiments, that objects are ſeldom viſible under an angle leſs than 40 ſeconds, and at a medium not leſs than two minutes.

A ſimple object, as a white or black ſquare, upon

upon the oppofite colour, is perceivable under a lefs angle than the parts of a compound one. The more objects differ in colour, the more eafily we can diftinguifh their feveral impreffions on the retina: different degrees of light on the fame object will render it vifible at different diftances, and under different angles; indeed the moft general caufe of the non-vifibility of objects, is the want of fufficient light in the pencils that proceed from them; feveral contiguous objects are fcarce difcernible one from the other, unlefs they each fubtend angles that are not lefs than four minutes.

A long flender object is vifible under a fmaller angle than a fquare object of the fame breadth: a flender object, as a line, may be confidered as confifting of feveral fquares joined together; and though one of thefe fquares may be too fmall to be feen, yet the pencils of light coming from each of them being contiguous, and ftriking at the fame time upon the retina, are capable, by their united ftrength, to awaken the vifive faculty, and fo to render the objects vifible from whence they came. For the fame reafon, *a fmall object in motion* is eafier difcerned than if at reft, and may be vifible in the one cafe, though not in the other. A fmall ftar, by day or twilight,

that cannot be eaſily ſeen through a teleſcope directed to it, will become viſible by ſhaking or moving the teleſcope.

There is a great difference in the degree of ſenſibility of different eyes. We have been told of perſons ſeeing a ſatellite of Jupiter without the aſſiſtance of glaſſes: a circumſtance that to many appears incredible. But when we conſider how much the various circumſtances of light affect viſion, and how much further our ſight is extended at ſome favourable opportunities than at others, theſe extraordinary accounts may be the more readily credited.

The following calculation of M. de la Hire will give ſome idea of the extreme ſenſibility of the optic nerves. The ſail of a windmill, ſix feet in diameter, may be eaſily ſeen at the diſtance of 4000 toiſes, and the eye being ſuppoſed to be an inch in diameter, the picture of this ſail at the bottom of the eye will be the eight thouſandth part of an inch. This ſhews with what wonderful accuracy the rays of light are refracted by the eye, ſo that a pencil of rays coming from one point of the object, ſhall meet in a point on the retina, ſo as not to deviate the eight thouſandth part of an inch.

If

If an object be held too close to the eye, it becomes indistinct, and the more so the closer it is held, notwithstanding it's apparent magnitude is thereby increased, and a very slender object will become totally invisible.

To the generality of eyes, the nearest distance of distinct vision is about seven or eight inches; at this distance they commonly read a small print, and examine all minute objects. It is true some eyes can see small objects best at the distance of six, four, and even three inches; and some again at twelve, fifteen, or twenty inches; but these are only particular cases, and do not, therefore, affect the present inquiry.

Of distinct and indistinct Vision.

It will be proper in this place to explain, with more accuracy, what is meant by distinct vision, and what is the difference between seeing an object distinctly, and seeing it clearly; as the clearness or brightness with which an object is seen, is often confounded with distinct vision.

We see an object *clearly*, when it is sufficiently illuminated, to enable us to form a general idea of it's figure, and distinguish it from other objects:

jects: we see it *distinctly*, when the outlines of it are well defined, when we can distinguish the parts of it, and determine their colour and situation. Thus we may be said to see a distant object *clearly*, when we can perceive that it is a tower; but to see it *distinctly*, we approach so near as to be able to determine not only it's general outline, but to distinguish the parts of which it is composed.

This may be made more evident, by adverting to the experiment of the dark chamber, in which we shall find a considerable difference between the distinctness and brightness of the picture; and learn, that a confusion of the parts is not the same thing with obscurity.

For the picture may be distinct in all it's parts; the rays which come from one and the same point in the object, may be exactly collected into one and the same point upon the paper; and yet, if but few rays pass through the lens, and consequently the space where the picture is painted should be but faintly enlightened, this picture, though it is distinct, will be faint and obscure. On the other hand, though the picture be confused, either because the paper is placed at an improper distance from the lens, or for any other

other caufe; yet if many rays pafs through the lens, and ftrongly illuminate the paper, the picture, notwithftanding the want of diftinctnefs, will be a bright one.

The brightnefs or clearnefs with which an object is feen, depends principally on the following circumftances.

1. On the quantity of light proceeding from the object to the eye, and this is in a great meafure regulated by the diftance, for the intenfity of light diminifhes in an inverfe ratio to the fquare of the diftances.

2. It depends on the colour of the object itfelf, and of thofe objects which furround it.

3. On the manner in which the light falls upon the object, and is reflected from it.

4. On the aperture of the pupil, for the wider this is, the greater will be the number of rays that are tranfmitted to the retina.

5. On the tranfparency and purity of the humours of the eye, and the foundnefs of the reft of the vifive parts.

6. On the tranſparency of the atmoſphere.

When all theſe circumſtances concur, an object will appear bright and clear; but leſs ſo, in proportion as any of them are wanting. In order, however, to obtain diſtinct viſion, it is requiſite, not only that the object be ſufficiently illuminated, but alſo that the ſeveral pencils, on their arrival at the retina, ſhould be ſeparate, and not mixed together, and when this is not the caſe, the outlines of the object and it's parts will appear faint, hazy, and ill-defined. We may, therefore, conſider the *following conditions as neceſſary towards obtaining diſtinct viſion.*

1. The objects ſhould be ſufficiently illuminated: now all other circumſtances being the ſame, the nearer an object is, and the brighter it's colour, the more light the eye receives from it; this is one reaſon why near objects are more diſtinctly ſeen than thoſe that are remote.

2. The geometrical image of objects ſhould fall either upon the retina, or very near it, and theſe images ſhould be ſufficiently large, otherwiſe the parts of the object cannot be diſtinctly perceived: the want of ſize in this image is alſo a cauſe of the indiſtinctneſs of remote objects.

3. It

3. It is alſo requiſite that the eye be in perfect order, and it's humours tranſparent, in order that the impreſſions of light may be lively and diſtinct.

In a given eye, and a given diſpoſition of that eye, an image upon the retina will be moſt perfect when the object is at ſome determinate diſtance from the eye, and it is near this point or place, that objects, if they are not too ſmall, will be diſtinctly ſeen. An object at a greater or leſs diſtance, will have it's image either before or behind the retina; and in either caſe, if the diſtance of the image from the retina be conſiderable, the viſion will be indiſtinct.

Dr. Jurin has, however, ſhewn that it is not neceſſary to diſtinct viſion, that the images of objects, or the points of union of the rays be preciſely upon the retina, there being ſome latitude both before and behind the retina, within which, whatever images be formed, the viſion will be equally diſtinct, and this latitude will be greater or leſs, according as the viſual angles, ſubtended by the reſpective objects, are greater or leſs.

Let a printed page, in which there are letters of three or four different ſizes, be placed at ſuch

a diſ-

a diſtance, that every ſort of print may, without any ſtraining or effort of the eye, be perfectly diſtinct; in this caſe it may be reaſonably preſumed, that the images of the ſeveral letters fall upon the retina. If the printed leaf be brought gradually nearer and nearer, the ſmalleſt print will firſt begin to be confuſed, whilſt the larger remains as diſtinct as before: by advancing it ſtill nearer, the ſmaller print will become more confuſed, the next ſize above it a little confuſed, whilſt the large print is ſtill as legible as before, and ſo through ſeveral degrees, till the whole is in confuſion.

The ſame experiment may be made the contrary way, by uſing a pair of ſpectacles, of a proper convexity. From hence it is evident, that we may have diſtinct viſion, when the focuſes of the pencils are at ſome diſtance, either before or behind the retina, and that the larger the object, the greater is this latitude.

But as in this caſe the pencils from every point either meet before they reach the retina, or tend to meet beyond it, the light that comes from them muſt cover a circular ſpot upon it, and will, therefore, paint the image larger than perfect viſion would repreſent it: and conſequently, every

every object, placed either too near or too remote for perfect viſion, will appear larger than it is, by a penumbra of light, cauſed by the circular ſpaces, which are illuminated by pencils of rays proceeding from the extremities of the objects. Theſe circular ſpaces are called circles of diſſipation. This accounts for ſhort-ſighted perſons finding near objects appear rather magnified, when they uſe a concave that is not ſo deep as that to which they are accuſtomed.

On account of theſe penumbræ, it is clear that two ſtars will appear to be nearer than they really are; and if they be really very near, will appear to be but one, but brighter than either of them taken alone: ſo that the two ſtars will have the ſame appearance as if one brighter ſtar appeared in the middle of the ſpace occupied by two ſtars.

When objects are large, they will appear tolerably diſtinct at a much leſs diſtance than ſmall objects, becauſe the penumbræ will not interfere ſo much. For this reaſon, a large print may be read much nearer the eye than a ſmall one; the former will appear only ill-defined, but ſufficiently diſtinct, when the latter is quite in-

diſtinct,

diſtinct, the penumbra of one letter interfering with *that* of another.

It is very difficult to aſcertain preciſely the natural diſtance of diſtinct viſion, or that diſtance at which the eye, without any ſtrain or effort, is ſuited to ſee objects diſtinctly. If we ſuppoſe this diſtance to be that at which we uſually read a large fair print, this will be about fifteen or ſixteen inches, and leſs it cannot be, as we are rather more concerned with large objects than the letters of a book; and when we view objects nearer, it is on account of their minuteneſs: nor is it probable that the diſtance can be many feet, as, in order to examine objects, we are always deſirous to have them near the eye, except they are very large. The neareſt diſtance of diſtinct viſion is in general computed to be at about ſeven or eight inches from the eye. *That point in any object to which the optic axis is directed is ſeen more diſtinctly than the reſt.* The truth of this poſition is confirmed by every one's own experience: if we turn our eyes directly toward one particular part of an object ſo as to look ſteadily at it, we may indeed, if the object be not very large, ſee all the reſt of it at the ſame time; but this part will appear more diſtinct than the reſt: but look-

ing

ing ſteadily at an object is turning our optic axis towards it.

Of the Change in the Conformation of the Eye for diſtinct Viſion, at different Diſtances.

As a ſhip requires a different trim for every variation of the direction and the ſtrength of the wind, ſo, if we may be allowed to borrow that word, the eyes require a different trim for every degree of light, and for every variation in the diſtance of the object, while it is within certain limits. The eyes are trimmed for a particular object, by contracting certain muſcles, and relaxing others; as the ſhip is trimmed for a particular wind, by drawing ſome ropes, and ſlackening others. The ſailor learns this trim of his ſhip, as we learn the trim of our eyes, by experience.*

A ſhip, although it be the nobleſt machine that human art can boaſt, is far inferior to the eye, for it requires art and ingenuity to navigate her, and the ſailor muſt know what ropes to pull, and which to ſlacken, to accommodate her to a particular wind. But the eye is fabricated with ſuch ſuperior wiſdom, and the principles of it's motion

* Reid's Inquiry into the Human Mind.

motion ſo contrived, that it requires no art nor ingenuity to ſee by it: we have not to learn what muſcles we are to contract, nor which we are to relax, in order to fit the eye to a particular diſtance of the object.

But although we are not conſcious of the motions we perform, in order to fit the eyes to the diſtance of the object, we are conſcious of the effort employed in producing theſe motions, and probably have ſome ſenſation which accompanies them, and to which we give as little attention as to many other ſenſations; and thus a ſenſation either previous or conſequent upon that effort, comes to be conjoined with the diſtance of the object which gave occaſion to it, and by this conjunction becomes one of the ſigns of that diſtance.

That we are capable of viewing objects with nearly equal diſtinctneſs, though they be placed at conſiderable diſtances from each other, is evident; but the alteration which takes place in the eye for this purpoſe, or the mechaniſm by which this effect is produced, is not eaſily aſcertained.

It ſeems clear from the firſt view of the ſubject,

ject, that when ſeveral objects are at different diſtances before us, they will not appear equally diſtinct at the ſame time. Leſt it ſhould be ſuſpected that the indiſtinctneſs in this caſe may be owing to the impreſſions not being made upon the correſponding fibrils of the two retinas, let us make a trial with one eye alone, while the other is ſhut: thus place two ſmall objects, as two pins, one behind the other, and let the one be at a foot, and the other at about ſix inches diſtance from the eye. Either of theſe objects, when looked at attentively, will appear diſtinct; but the other, at the ſame time, although it be in the axis of the eye, will be confuſed. And from hence it is very clear, that the ſame conformation of the eye is not adapted for diſtinct viſion at all diſtances, and that the eye by ſome means changes it's conformation, ſo as it may be better ſuited for viſion at different diſtances.

In a ſimilar manner to the foregoing experiment, if the eye looks attentively upon the little ſcratches or particles of duſt upon a window-glaſs, the objects without doors will be indiſtinct; and when we look at the external objects, the opake particles upon the glaſs, which before were diſtinct, will now be confuſed. It alſo frequently happens, that when we firſt look at an object,

object, it will appear very confuſed, which confuſion will vaniſh by degrees, and in a little time the object will become quite diſtinct.

In like manner, if after poring ſome time on a book, we ſuddenly look at objects farther off, they will at firſt appear confuſed, and become diſtincter by degrees. A ſimilar indiſtinctneſs takes place, when from looking at remote objects, we ſuddenly look at one that is near. To what can we attribute theſe phænomena, but to a change in the conformation of the eye for viſion at theſe different diſtances; a change which requires ſome ſmall time for it's performance. It cannot be owing to the laſt impreſſion on the eye not being obliterated; for in that caſe, the ſame confuſion would be obſervable upon ſhifting the eye from one page of a book to the other.

Theſe phænomena are ſtronger when they happen without our thinking upon them; for when we make the experiment on purpoſe, and the mind is already prepared for what is to happen, it has time in part to fruſtrate our deſign; the more ſo, as theſe changes are ſomewhat painful.

Authors are much divided in their opinions concerning

concerning the change that is made in the conformation of the eye, to procure diſtinct viſion at different diſtances, ſome thinking it to be a change in the length of the eye, others that it is a change in the figure or poſition of the cryſtalline humour, others that it is a change in the cornea. The authors of each opinion have their objections to all the reſt, and perhaps the truth may lie among them all. As the rays of light ſuffer a greater refraction at the cornea than they do afterwards, it is plain that a leſs change, as to quantity, in the radius of the cornea, will effect the buſineſs, than would be ſufficient in any other part of the eye: but at the ſame time it muſt alſo be confeſſed, that moſt perſons who have been couched for cataracts, are obliged to have glaſſes of different convexities, in order to have diſtinct viſion at different diſtances; from whence it ſeems neceſſarily to follow, that the cryſtalline humour is concerned in changing the conformation of the eye. Perhaps the cornea, and the cryſtalline, if not ſome other parts of the eye beſides, may contribute to produce this effect: and in order to obtain diſtinct viſion at a nearer diſtance, at the ſame time the cornea is rendered more convex, the axis of the eye may be a little lengthened, the cryſtalline made more convex and brought forwarder, all which changes con-

ſpire to the ſame end; and the contrary for obtaining viſion at a greater diſtance.

It has been ſhewn by writers on optics, that if an object be viewed diſtinctly at three different diſtances from the eye, the firſt of which may be the leaſt diſtance at which it can be viewed diſtinctly, the ſecond double the firſt, and the third infinite, that the alterations in the conformation of the eye, neceſſary for viewing an object diſtinctly at the firſt and ſecond diſtances, whoſe difference is but ſmall, are as great as thoſe that are neceſſary for the ſecond and third, whoſe difference is infinite.

Hence, if a ſhort-ſighted perſon can read a ſmall print diſtinctly, at two different diſtances, whereof the larger is but double the leſſer, as great alterations are made in his eyes, as in one whoſe eyes are perfect, and that can ſee diſtinctly at all intermediate diſtances, between infinity and the largeſt of the two former diſtances. For the ſame reaſon, a ſhort-ſighted perſon can ſee diſtinctly at all diſtances, with a ſingle concave of a proper figure; for the cauſe of ſhort-ſightedneſs is not a want of power to vary the conformation of the eye, but that the whole quantity

quantity of refractions is always too great for the diſtance of the retina from the cornea.

We may hence alſo clearly perceive why our eyes are ſo ſoon fatigued in looking at near objects; for in this caſe, the muſcles of the eyes, and the ligamentum ciliare, are obliged to make a conſiderable effort, to give the eyes the neceſſary conformation, which effort being greater in proportion as the object is nearer, muſt be painful and laborious when the object is very nigh.

When the eye has been attentively fixed on an object at ſome determined diſtance, it cannot immediately ſee another object diſtinctly; whether it be at a greater or leſſer diſtance, it appears confuſed and imperfect, till the eye has adapted itſelf to the diſtance at which the object is placed.

Of the Pupil of the Eye, and of it's Motions.

In ſpeaking of the ſtructure of the eye, we have ſhewn that the uvea has a ſmall round hole nearly in the middle, called the *pupil*, through which the rays muſt all paſs before they can get to the bottom of the eye, and paint the images of objects on the retina. The conſideration of

the various affections of this part of the eye, will be found of great importance, both to the vender and purchaser of spectacles; for upon the state and aperture of the pupil, the requisite degree of magnifying power very much depends.

The author of nature has proportioned the magnitude of the pupil, so that it may best answer the purposes of vision, and the sensibility of the retina: if it were too large, the retina would be fatigued, and hurt by the great quantity of light. Hence it is that those creatures cannot bear the light of day, which, in order to search for and procure their food at night, have the pupil of their eyes very large. Further, if this aperture had been much larger than it really is, the eye would not have been a dark cell, and so much adventitious light would have entered, as to render the picture upon the retina obscure and indistinct: for as in the camera obscura, the pictures are most lively and perfect when all the light is excluded, but what comes from the object, and serves to form the picture; so it is with our eyes; the picture on the retina is most perfect when all extraneous light is excluded, and none mixes with the picture, but what tends to it's formation.

On

On the other hand, if the pupil had been very ſmall, it would not have admitted a ſufficient quantity of light; the impreſſion on the retina would have been weak, and the picture faint and obſcure; when the pupil is very ſmall, convex glaſſes are neceſſary, in order to increaſe the quantity of light.

All animals have a power of contracting and dilating the pupil of their eyes. The natural ſtate appears to be that of dilatation, and the contraction a ſtate of violence, produced by an effort originating in the mind. When the light is too ſtrong, or the object too bright, we contract the pupil, to intercept that part of the light which would injure the eye; but when the light is weak, we dilate the pupil, that more light may enter the eye. If a perſon look towards the ſun, you will obſerve the pupil become exceeding ſmall; but if he turns his eyes from the light, and be gradually brought into a dark place, you will obſerve the pupil to dilate, in proportion as the light becomes more faint and obſcure.

There are alſo other circumſtances which will cauſe the pupil to contract, as when the object is nearer the eye than the limits of diſtinct viſion:

ſion: for in this caſe, the pencils of rays proceeding from the object are too diverging to be united in correſponding points on the retina; but by contracting the pupil, many of the rays are excluded, and the picture is rendered more diſtinct. It is for this purpoſe, that many ſhort-ſighted perſons contract a habit of corrugating their eyebrows in reading, a habit which would be prevented by the uſe of concave ſpectacles.

Dr. Jurin has ſhewn, that the contraction of the pupil does, in general, depend more upon the ſtrength of the light, than on the ſenſation of confuſion in the object. Let any perſon take a book by day-light, and ſtand near the middle of a room, with his back to the light, and then hold the book ſo near, that the letters may appear indiſtinct, but not ſo much ſo, but that they may be read, though with difficulty; on turning towards the light, it will be read with more eaſe. Again, holding the book at the ſame diſtance, go into the darkeſt part of the room, and ſtanding with your back to the light, you will find the book not at all legible; but on coming to the window, with your face to the light, you will be able to read with eaſe and diſtinctneſs. A perſon who has uſed ſpectacles

for

for ſome years, will in the ſun-ſhine be able to read without them.

When we have been for ſome time in a place much illuminated, or if the eye has been too long expoſed to a reſplendent object, and then views objects that are leſs ſo, or goes into a darker place, the ſight will for a little time be impaired, and the eye unable to perform it's proper functions. The ſame will alſo happen from the contrary circumſtances, if we go from a faint light into one that is much brighter; in either caſe the pupil has not time to conform itſelf to the ſudden,* but neceſſary change, for ſeeing diſtinctly under the new circumſtances. From hence we may infer, that very opake ſhades round a candle, inſtead of preſerving and protecting the eye, muſt be neceſſarily prejudicial to it. A moderate degree of opacity in the ſhade, as that of thick paper, may, by leſſening the degree of light, be uſeful to eyes which are inflamed or have a tendency to inflammation.

* This is what Potterfield and ſome others ſay; but from other experiments, the pupil is never ſo contracted as in the caſe of going ſuddenly from a faint to a bright light: the contraction is inſtantaneous. The effects, therefore, ſpoken of above, muſt be referred to the different ſtates of the ſenſibility of the retina.

There is a kind of ſympathy, or concord, in the motion of the pupils of both eyes, ſo that when one is contracted, the other contracts alſo; when one is dilated, the other alſo dilates, though neither the dilatation nor contraction are equal. Many groſs overſights have ariſen, and ſome dangerous miſtakes have been made, by oculiſts, according to Potterfield, from their not attending to this fundamental law concerning the pupil.

From this expanding and contracting power of the eye, we may learn, why the eye ſees beſt when ſurrounded with darkneſs; for the pupil, by dilating, accommodates itſelf as much as poſſible to the quantity of light, dilating conſiderably when the eye is in darkneſs, and, *cæteris paribus*, objects are ſeen moſt clearly when the pupil is moſt dilated; beſides, when the eye is in the dark, the picture on the retina is neither confuſed nor diſturbed by adventitious rays; hence, thoſe who are in a very bright light, when they want to diſtinguiſh accurately a diſtant object, either depreſs the eyebrows, or apply the hand to the forehead: hence alſo, a perſon, by placing himſelf in the dark, and employing a long tube, will form a ſpecies of teleſcope, producing a greater effect than might at firſt be conceived: it was on this principle that the ancients uſed

ufed a deep pit, in order to fee the ftars in the day-time. From hence we alfo learn, why a perfon from within a chamber can perceive the objects that are without, while thofe that are out of doors cannot fee the objects that are within: for when we are out of doors, the pupil is contracted, and only a fmall portion of the light that is reflected from the objects within the chamber, can pafs to the retina; while on the contrary, thofe within have the pupil more dilated, and the objects that are without are alfo more ftrongly illuminated; befides which, their view of objects is not much obftructed by the reflection of the window-glafs.

It is furprizing how far the eye can accommodate itfelf to darknefs, and make the beft of a gloomy fituation. When firft taken from the light, and brought into a dark room, all things difappear; or if any thing is feen, it is only the remaining radiations that ftill continue in the eye; but after a very little time, the eye takes advantage of the fmalleft ray, which is confirmed by the following curious account, related by Mr. Boyle. In the time of Charles the firft, there was a gentleman, who, fharing in his worthy mafter's misfortunes, was forced abroad; at Madrid, in attempting to do his king a fignal fervice,

ſervice, he failed; in conſequence of this, he was confined in a dark and diſmal dungeon, into which the light never entered, and into which there was no opening but by a hole at the top, down which the keeper put his proviſions, preſently cloſing it again. The unfortunate loyaliſt continued for ſome weeks in this dark dungeon, quite diſconſolate; but, at laſt, began to think he ſaw ſome glimmering of light: this dawn of light increaſed from time to time, ſo that he could not only diſcover the parts of his bed, and ſuch other large objects, but, at length, he could perceive the mice that frequented his dungeon, to eat the crumbs that fell upon the ground. When ſet at liberty, he could not, for ſome days, venture to leave his cell, leſt the brightneſs of the light ſhould blind him; but was obliged to accuſtom his eyes, by ſlow and gradual degrees, to the light of the day.

Of imperfect Sight.

There is no branch of ſcience, of which it is more important that a general knowledge ſhould be diffuſed, than that part which treats of the various imperfections of ſight, and the remedies for them. To relieve an organ which is the ſource of the moſt refined pleaſure, is certainly a deſirable

desirable object: to enable those who are in want of assistance, to determine whether spectacles will be advantageous or detrimental, and what kind will best suit their sight; and so instruct those who already use glasses, that they may discover whether those they have chosen are adapted to the imperfection of their sight, or are such as will increase their complaint, and weaken their eyes, are subjects worthy the consideration of every individual, and constitute the principal business of the remainder of this work: to this end we shall, in the first place, explain what we mean by an imperfection of sight.

We here understand by imperfect sight, an absolute or relative debility of it, without any opacity, either in the cornea or other internal parts of the eye, and without any disease of the retina or optic nerve.

The sight is relatively imperfect, when we cannot see an object distinctly in a common light, and at all the usual distances at which it is observed by an eye in a perfect state.

In this sense, both the long and short-sighted are said to have an imperfect sight. The short-sighted see distant objects confusedly, those that are

are near at hand diſtinctly; their ſight is therefore defective with reſpect to diſtant objects: on the other hand, the long-ſighted ſee diſtant objects diſtinctly, near objects confuſedly.

An imperfect ſight is occaſioned by a confuſion in the image formed upon the retina; this happens whenever all the rays that proceed from any one point of an object, are not united again in one, but fall on different points of the retina: or whenever ſeveral pencils of light, from different points of an object, terminate upon one point of the image. This ſpecies of confuſion takes place both in long and ſhort-ſighted eyes.

An imperfect ſight differs from an amauroſis or gutta ſerena; for in the latter the ſight is entirely loſt, and the pupil becomes immoveable; though if one eye remain ſound, the pupil of the blind eye will be moved with the pupil of the ſound one; but if the ſound eye be ſhut, the pupil of the blind eye will be deſtitute of motion.

Of old or long-ſighted Eyes.

To detail thoſe circumſtances which are, in general, marks of advancing age, and always of partial infirmity, muſt be ever unpleaſant, and would

would be equally unneceſſary, if it were not the mean of leſſening the inconveniences attendant on thoſe ſtages of life.

By the long-ſighted, remote objects are ſeen diſtinctly, near ones confuſedly; and in proportion as this defect increaſes, the nearer objects become more indiſtinct, till at length it is found almoſt impoſſible to read a common-ſized print without aſſiſtance. An imperfect and confuſed image is formed upon the retina, becauſe the rays of light that come from the ſeveral points of an object, at an ordinary diſtance, are not ſufficiently refracted, and therefore do not meet upon the retina, but beyond it.

Various are the cauſes which may occaſion this defect; if the convexity of the cornea be leſſened, or if either ſide of the cryſtalline becomes flatter, this effect will be produced; if the retina be not ſufficiently removed from the cornea or cryſtalline, or if the retina be too near the cornea or cryſtalline, it will give riſe to the ſame defect, as will alſo a leſs refractive power in the pellucid parts of the eye; in like manner, too great a proximity of the objects, will prevent the rays from uniting till they are beyond the retina; but if all theſe cauſes concur together, the effect

is greater. This defect is, however, in general, attributed to a shrinking of the humours of the eye, which causes the cornea and crystalline to lose their original convexity, and to become flatter; the same cause will bring the retina too near the cornea.

By one or other of these causes, those who were accustomed in their youth to read a common size print, at about twelve or fourteen inches distance from their eyes, are obliged to remove the book to two or three feet before they can see the letters distinctly, and read with comfort. But in proportion as the object is removed from the eye, the image thereof on the retina becomes smaller, and consequently small objects will not always be perceivable at that distance, to which those in this state find it necessary to remove them, in order to attain any degree of distinct vision: the further also the object is removed, the less light will enter the eye, and the image will, of course, be fainter.

Hence, those who are long-sighted require more light to enable them to read, than they did while their eyes were in their perfect state; and this not only because they are obliged to remove the book to a greater distance, but because the

pupil

pupil of their eye is ſmaller, and therefore a greater intenſity of light is neceſſary to produce a ſufficient impreſſion on the retina, and compenſate for the defect by a greater ſplendor and illumination of the object.

Increaſing years have a natural tendency to bring on this defect, and earlier among thoſe who have made the leaſt uſe of their eyes in their youth; but whatever care be taken of the ſight, the decays of nature cannot be prevented: the humours of the eye will gradually waſte and decay, the refractive coats will become flatter, and the other parts of the eye more rigid and leſs pliable; thus the latitude of diſtinct viſion will become contracted: it is alſo highly probable, that the retina and optic nerve loſe a portion of their ſenſibility.

Though it is in the general courſe of nature, that this defect ſhould augment with age, yet there are not wanting inſtances of thoſe who have recovered their ſight at an advanced period, and have been able to lay aſide their glaſſes, and read and write with pleaſure, without any artificial aſſiſtance. Among many cauſes which may produce this effect, the moſt probable is, that it generally ariſes from a decay of the fat in

the

the bottom of the orbit; the preſſure in this part ceaſing, the eye expands into ſomewhat of an oval form, and the retina is removed to a due focal diſtance from the cryſtalline.

It is a certain and very important fact, that long-ſightedneſs may be acquired; for countrymen, ſailors, and thoſe that are habituated to look at remote objects, are generally long-ſighted, want ſpectacles ſooneſt, and uſe the deepeſt magnifiers; on the other hand, the far greater part of the ſhort-ſighted are to be found among ſtudents, and thoſe artiſts who are daily converſant with ſmall and near objects; every man becoming expert in that kind of viſion, which is moſt uſeful to him in his particular profeſſion and manner of life: thus the miniature painter, and engraver, ſee very near objects better than a ſailor; but the ſailor perceives diſtant objects better than they do: the eye in both caſes endeavouring to preſerve that configuration to which it is moſt accuſtomed. In the eyes, as well as other parts of the body, the muſcles, by conſtant exerciſe, are enabled to act with more eaſe and power, but are enfeebled by diſuſe; the elaſtic parts alſo, if they are kept too long ſtretched, loſe part of their elaſticity; while on the other hand, if they be ſeldom exerciſed, they grow ſtiff, and

and are not eaſily diſtended. From the conſideration of theſe facts, we may learn, in a great meaſure, how to preſerve our eyes; by habituating them occaſionally to near as well as diſtant objects, we may maintain them longer in their perfect ſtate, and be able to poſtpone the uſe of ſpectacles for many years; but we may alſo infer from the ſame premiſes, that there is great danger, when the eyes are become long-ſighted, of deferring too long the uſe of ſpectacles, or uſing thoſe that magnify too much, as we may by either method ſo flatten the eye, as to loſe entirely the benefits of naked viſion. It may not be improper in this place to remark, that the long-ſighted eye is much more liable to be injured by too great a degree of light, than thoſe that are ſhort-ſighted.

Objects that appear confuſed to the long-ſighted, will be rendered more diſtinct, if they view them through a ſmall hole, ſuch as that made by a pin in a card, becauſe it excludes thoſe diverging rays which are the principal ſource of confuſion; but as it, at the ſame time, intercepts a conſiderable portion of the light, it is by no means an adequate remedy. The beſt relief they can obtain is from convex glaſſes, for by theſe the rays of light that proceed from

the object, are ſo refracted, as to fall upon the retina, in the ſame manner as if they iſſued from a diſtant point. Spectacles afford two advantages, for they not only render the picture of objects diſtinct upon the retina, but they alſo make it ſtrong and lively.

Of Spectacles.

The diſcovery of optical inſtruments may be eſteemed among the moſt noble, as well as among the moſt uſeful gifts, which the Supreme Artiſt hath conferred on man. For all admirable as the eye came out of the hands of him who made it, yet he has permitted this organ to be more aſſiſted by human contrivance, than any other of the animal frame, and that not only for the uſes and comforts of common life, but for the advancement of natural ſcience; whether by giving form and proportion to the minute parts of bodies, that were imperceptible to the unaſſiſted ſight, or by contracting ſpace, and as by magic art, bringing to view the grander objects of the univerſe, which were rendered inviſible by their immenſe diſtance from us. * Noble as theſe inventions are, the diſcovery of ſpectacles may

* Sir John Pringle's Six Diſcourſes.

may ſtill claim the ſuperiority, as being of more univerſal benefit, and more extenſive uſe. They reſtore and preſerve to us one of the moſt noble and valuable of our ſenſes; they enable the mechanic to continue his labour, and earn a ſubſiſtence by the work of his hand, till the extreme of old age. By their aid the ſcholar purſues his ſtudies, and recreates his mind with intellectual pleaſures, and thus paſſes away days and years with delight and ſatisfaction, that might otherwiſe have been devoured by melancholy, or waſted by idleneſs.

As ſpectacles are deſigned to remedy the defects of ſight, it is natural to wiſh, that the materials of which they are formed ſhould be as perfect as the eye itſelf; but vain is the wiſh, for the materials we uſe, like every thing human, are imperfect, and yet we may deem ourſelves happy, to have in glaſs a ſubſtitute ſo analagous to the humours of the eye, a ſubſtance which gives new eyes to decrepid age, and enlarges the views of philoſophy. The two principal defects are, ſmall threads or veins in the glaſs, and minute ſpecks. The threads are moſt prejudicial to the purpoſes of viſion, becauſe they refract the rays of light irregularly, and thus diſtort the object, and fatigue the eye; whereas the ſpecks

 only

only lessen the quantity of light, and that in a very small degree.

General Rules for the Choice of Spectacles.

The most general, and perhaps the best rule that can be given, to those who are in want of assistance from glasses, in order so to choose their spectacles, that they may suit the state of their eyes, is to prefer those which shew objects nearest their natural state, neither enlarged nor diminished, the glasses being near the eye, and that give a blackness and distinctness to the letters of a book, neither straining the eye, nor causing any unnatural exertion of the pupil.

For no spectacles can be said to be properly accommodated to the eyes, which do not procure them ease and rest; if they fatigue the eyes, we may safely conclude, either that we have no occasion for them, or that they are ill made, or not proportioned to our sight.

Though, in the choice of spectacles, every one must finally determine for himself, which are the glasses through which he obtains the most distinct vision; yet some confidence should be placed in the judgment of the artist, of whom they

they are purchaſed, and ſome attention paid to his directions. By trying many ſpectacles the eye is fatigued, as the pupil varies in ſize with every different glaſs, and the eye endeavours to accommodate itſelf to every change that is produced. Hence, the purchaſer often fixes upon a pair of ſpectacles, not the beſt adapted to his ſight, but thoſe which ſeem to relieve him moſt, while his eyes are in a forced and unnatural ſtate; and conſequently, when he gets home, and they are returned to their natural ſtate, he finds what he had choſen, fatiguing and injurious to his ſight.

Of Preſervers, and Rules for the Preſervation of the Sight.

Though it may be impoſſible to prevent the abſolute decay of ſight, whether ariſing from age, partial diſeaſe, or illneſs, yet by prudence and good management, it's natural failure may certainly be retarded, and the general habit of the eyes ſtrengthened, which good purpoſes will be promoted by a proper attention to the following maxims.

1. Never to ſit for any length of time in abſolute gloom, or expoſed to a blaze of light.

The reaſons on which this rule is founded, prove the impropriety of going haſtily from one extreme to the other, whether of darkneſs or of light, and ſhew us, that a ſouthern aſpect is improper for thoſe whoſe ſight is weak and tender.

2. To avoid reading a ſmall print.

3. Not to read in the duſk; nor, if the eyes be diſordered, by candle-light. Happy thoſe who learn this leſſon betimes, and begin to preſerve their ſight, before they are reminded by pain, of the neceſſity of ſparing them; the frivolous attention to a quarter of an hour of the evening, has coſt numbers the perfect and comfortable uſe of their eyes for many years: the miſchief is effected imperceptibly, the conſequences are inevitable.

4. The eye ſhould not be permitted to dwell on glaring objects, more particularly on firſt waking in a morning; the ſun ſhould not of courſe be ſuffered to ſhine in the room at that time, and a moderate quantity of light only be admitted. It is eaſy to ſee, that for the ſame reaſons, the furniture of a bed ſhould be neither altogether of a white or red colour; indeed, thoſe whoſe

whose eyes are weak, would find considerable advantage in having green for the furniture of their bed-chamber. Nature confirms the propriety of the advice given in this rule: for the light of the day comes on by slow degrees, and green is the universal colour she presents to our eyes.

5. The long-sighted should accustom themselves to read with rather less light, and somewhat nearer to the eye than what they naturally like; while those that are short-sighted, should rather use themselves to read with the book as far off as possible. By this means, both would improve and strengthen their sight; while a contrary course will increase it's natural imperfections.

There is nothing which preserves the sight longer, than always using, both in reading and writing, that moderate degree of light which is best suited to the eye; too little strains them, too great a quantity dazzles and confounds them. The eyes are less hurt by the want of light, than by the excess of it; too little light never does any harm, unless they are strained by efforts to see objects, to which the degree of light is inadequate; but too great a quantity has, by it's

own power, deſtroyed the ſight. Thus many have brought on themſelves a cataract, by frequently looking at the ſun, or a fire; others have loſt their ſight, by being brought too ſuddenly from an extreme of darkneſs into the blaze of day. How dangerous the looking upon bright luminous objects is to the ſight, is evident from it's effects in thoſe countries which are covered the greater part of the year with ſnow, where blindneſs is exceeding frequent, and where the traveller is obliged to cover his eyes with crape, to prevent the dangerous, and often ſudden effects of too much light: even the untutored ſavage tries to avoid the danger, by framing a little wooden caſe for his eyes, with only two narrow ſlits. A momentary gaze at the ſun, will, for a time, unfit the eyes for viſion, and render them inſenſible to impreſſions of a milder nature.

The following caſes from a ſmall tract on the "*Fabric of the Eye*," are ſo applicable to the preſent article, as to want no apology for their inſertion here; though if any were neceſſary, the uſe they will probably be of to thoſe whoſe complaints ariſe from the ſame or ſimilar cauſes, would, I preſume, be more than ſufficient.

"A lady

"A lady from the country, coming to refide in St. James's-fquare, was afflicted with a pain in her eye, and a decay of fight. She could not look upon the ftones, when the fun fhone upon them, without great pain. This, which fhe thought was one of the fymptoms of her diforder, was the real caufe of it. Her eyes, which had been accuftomed to the verdure of the country, and the green of the pafture grounds before her houfe, could not bear the violent and unnatural glare of light reflected from the ftones; fhe was advifed to place a number of fmall orange trees in the windows, fo that their tops might hide the pavement, and be in a line with the grafs. She recovered by this fimple change in the light, without the affiftance of any medicine; though her eyes were before on the verge of little lefs than blindnefs."

"A gentleman of the law had his lodgings in Pall-mall, on the north-fide, his front windows were expofed to the full noon fun, while the back room, having no opening, but into a fmall clofe yard, furrounded with high walls, was very dark; he wrote in the back room, and ufed to come from that into the front to breakfaft, &c. his fight grew weak, and he had a conftant pain in the balls of his eyes; he tried vifual glaffes, and

and ſpoke with oculiſts, equally in vain. Being ſoon convinced, that the coming ſuddenly out of his duſky ſtudy, into the full blaze of ſun-ſhine, and that very often in the day, had been the real cauſe of his diſorder; he took new lodgings, by which, and forbearing to write by candle-light, he was very ſoon cured."

Blindneſs, or at leaſt miſerable weakneſſes of ſight, are often brought on by theſe unſuſpected cauſes. Thoſe who have weak eyes, ſhould therefore be particularly attentive to ſuch circumſtances, ſince prevention is eaſy, but the cure may be difficult, and ſometimes impracticable.

I hope I ſhall not be thought to have ſtepped improperly out of the line of my profeſſion, in recommending the following remedy, when a decay or weakneſs of ſight comes on earlier than might reaſonably be expected, and without any diſeaſe, or other apparent cauſe; if it does not anſwer the purpoſe, no ill will attend the uſe of it. Put two ounces of roſemary leaves into a bottle, with a pint of brandy, ſhake it once or twice a day; let this ſtand three days, then ſtrain it off; mix a tea ſpoonful of the clear tincture with four tea ſpoonfuls of warm water, and waſh the

the inſide of the eye with it every night, moving about the eye-lids, that ſome of it may get perfectly in between the lid and the eye. By degrees put leſs and leſs water to the tincture, till at length a tea ſpoonful of each may be mixed for uſe.

Whatſoever care, however, be taken, and though every precaution be attended to with ſcrupulous exactneſs; yet as we advance in years, the powers of our frame gradually decay, an effect which is generally firſt perceived in the organs of viſion.

Age is, however, by no means an abſolute criterion, by which we can decide upon the ſight, nor will it prove the neceſſity of wearing ſpectacles. For, on the one hand, there are many whoſe ſight is preſerved in all it's vigour, to an advanced old age; while, on the other, it may be impaired in youth by a variety of cauſes, or be vitiated by internal maladies; nor is the defect either the ſame in different perſons of the ſame age, or in the ſame perſon at different ages; in ſome the failure is natural, in others it is acquired.

From whatever causes this decay arises, an attentive consideration of the following rules, will enable every one to judge for himself, when his sight may be assisted or preserved by the use of spectacles.

1. When we are obliged to remove small objects to a considerable distance from the eye, in order to see them distinctly.

2. If we find it necessary to get more light than formerly; as for instance, to place the candle between the eye and the object.

3. If on looking at, and attentively considering a near object, it becomes confused, and appears to have a kind of mist before it.

4. When the letters of a book run one into the other, and hence appear double and treble.

5. If the eyes are so fatigued by a little exercise, that we are obliged to shut them from time to time, and relieve them by looking at different objects.

When all these circumstances concur, or any of them separately take place, it will be necessary

to

to ſeek aſſiſtance from glaſſes, which will now eaſe the eyes, and in ſome degree check their tendency to grow flatter; whereas if they be not aſſiſted in time, the flatneſs will be conſiderably increaſed, and the eyes be weakened by the efforts they are compelled to exert.

We are now able to decide upon a very important queſtion, and ſay how far ſpectacles may be ſaid to be *preſervers of the ſight*. It is plain they can only be recommended as ſuch, to thoſe whoſe eyes are beginning to fail; and it would be as abſurd, to adviſe the uſe of ſpectacles to thoſe who feel none of the foregoing inconveniences, as it would be for a man in health to uſe crutches to ſave his legs. But thoſe who feel thoſe inconveniences, ſhould immediately take to ſpectacles, which, by enabling them to ſee objects nearer, and by facilitating the union of the rays of light on the retina, will ſupport and preſerve the ſight.

When the eye ſenſibly flattens, all delay is dangerous; and the longer thoſe who feel the want of aſſiſtance, defer the uſe of ſpectacles, the more they will increaſe the failure of the eye; there are too many who procraſtinate the uſe of them, till at laſt they are obliged to uſe glaſſes of

of ten or twelve inches focus, inſtead of thoſe of 36 or 40, which would otherwiſe have ſuited them; thus preferring a real evil, to avoid one that is imaginary. Mr. Thomin mentions ſeveral deplorable caſes of this kind, particularly one of a lady, who, through falſe ſhame, had abſtained from wearing ſpectacles ſo long a time, that at laſt it was impoſſible to ſuit her, but with thoſe adapted to eyes that have been couched. Whereas the inſtances are numerous of thoſe who, by uſing glaſſes of a long focus at the firſt approaches of long-ſightedneſs, have brought back their eyes to their natural ſight, and been able to lay aſide their ſpectacles for years.

Theſe conſiderations point out clearly the advantages that may be obtained by a proper choice of ſpectacles on firſt wearing them, and the importance of making ſuch a choice; as the eye will endeavour to conform itſelf to any improper focus, and thus be brought into a ſtate of extreme age, at a much earlier period than would have happened, had they been ſuited with judgment. There are very few opticians but what muſt have ſeen inſtances of thoſe, who, by habituating their eyes to too ſhort a focus, or too great a magnifying power, have ſo injured thoſe tender organs, as to deprive them of future

aſſiſtance

aſſiſtance from glaſſes. This frequently happens to thoſe who purchaſe their ſpectacles of hawkers and pedlars, men equally ignorant of the ſcience of optics, and the fabric of the eye.

Let it, therefore, be carefully remembered, that magnifying power is not the point that is moſt to be conſidered in the choice of ſpectacles, but their conformity to our ſight, their enabling us to ſee diſtinctly, and with eaſe, at the diſtance we were accuſtomed to read or work, before the uſe of ſpectacles became neceſſary: or, in other words, glaſſes ſhould ſo alter the diſpoſition of the rays, at their entrance into the eyes, as will be moſt ſuitable to procure diſtinct viſion at a proper diſtance; an end of the higheſt import, as in this reſpect it places the aged nearly on a level with the young, and enables him to read a common print with eaſe, at a period when, without aſſiſtance, he could hardly diſtinguiſh one letter from another.

In proportion as the eye flattens, glaſſes of greater convexity are to be uſed; but ſtill we ſhould be careful not to go too far: for if they magnify too much, they will fatigue the eye. The moſt certain criterion of their being too old for the actual ſtate of the ſight, is our being obliged

obliged to bring the objects we look at through them, nearer the eye than the common diſtance of diſtinct viſion. All glaſſes that cauſe us to depart much on either ſide from the limits of diſtinct viſion, may be conſidered as ill adapted, and prejudicial to the ſight.

Thoſe who are careful in following a regular gradation, may preſerve their eyes to the lateſt period of old age, and even then be able to enjoy the comforts and pleaſures that ariſe from diſtinct viſion. Do not, therefore, precipitate theſe changes, leſt you ſhould abſorb too ſoon the reſources of art, and not be able to find ſpectacles of ſufficient power to relieve the eye. One precaution more is neceſſary: by no means put on any ſpectacles but your own; for taking up, and wearing glaſſes different from thoſe to which your eye is accommodated, has the ſame ill effect as trying a variety at an optician's ſhop; this variety fatigues and diſturbs the ſight; all irregularity is injurious, and much of the preſervation of the ſight depends upon keeping it uniform, as well with regard to the glaſſes, as the degrees of light.

There are many who find the effect of candlelight ſo different from the purer light of day, that

that they are obliged to uſe ſpectacles by night, though they can do very well without them in the day. Theſe, when the eye has become more flat, will find it adviſeable to have two pair of ſpectacles, one to uſe by day, the other, magnifying ſomewhat more, appropriated for the night; by this means, nearly the ſame quantity of light may be brought to act upon the retina at one time as the other; thus the eyes will be leſs fatigued, and longer maintain their natural vigour.

Of Viſual Spectacles.

The natural deſire of men in trade to increaſe their buſineſs, and extend their fame, has in many inſtances been the origin of alterations and inventions, injurious to ſcience, and detrimental to the public. It is a deſire, to which all in trade are, from their ſituation, expoſed; and from which, it may be preſumed, no one is exempt.

To this deſire we may, with propriety, impute the invention of viſual ſpectacles; and as pretences are ſeldom wanting to juſtify that which intereſt adopts, the inventor endeavoured, by ſpecious reaſons, to attract the attention of thoſe who were not to be captivated by mere novelty. But the good ſenſe of the world, which always,

in the long run, justly appreciates the value of every invention, now leaves visual spectacles to the neglect they merit; they are worn by few, but those who, from long habit, have accustomed their eyes to these pernicious shades.

Among the reasons adduced by the inventor, the following is that upon which the greatest stress was laid, namely, that as in telescopes, microscopes, &c. we are obliged, by proper apertures, to cut off those extraneous rays which tend to render the image confused; so, in the same manner, the quantity of light should be adjusted in spectacles. To this it was then answered, that the cases were by no means analagous, and if they were, the reason alledged would operate against the use of visual glasses; for as all lenses bear an aperture proportional to their focal length, a lens of five inches focus, which is one of the shortest in general use, would bear a much larger aperture than the diameter of any spectacle eye; but there was surely no need of apertures to glasses, applied close to the eye, whose pupil is formed by nature to adapt itself to every degree of light; and we should in all cases, leave the eyes as much as possible to their own exertions and uniform mode of acting. Considered as a shade or screen, the horn rims of the visual glasses are imperfect

and

and detrimental, they are alſo inconvenient in uſe; for if the line to be read is long, the head muſt be in continual motion, to ſee the words, which are obſtructed by the opake rim; to theſe, and many other reaſons which might be adduced, we may add the proofs derived from experience and obſervation; by theſe I am fully convinced, that they are injurious to the eye, and that in general thoſe who wear them, uſe glaſſes of a ſhorter focus than thoſe who wear the common ſort.

If from the weakneſs of the eye a ſhade be neceſſary, let it be ſuch a one as is pointed out by nature: ſhe teaches us, that thoſe whoſe eyes are deep ſet, have the cleareſt and ſtrongeſt ſight; and that whenever we find the light too ſtrong we pull down our eye-brows, and if this be not ſufficient, put our hand over our eyes; by this we are inſtructed, that the beſt form for a ſhade is one fitted to the forehead, and projecting from it 2 or 3 inches.

It may not be improper in this place to ſay a word or two reſpecting ſhades or ſcreens for candles. I am clearly of opinion, that all opake ſhades are detrimental to the eye, as well from the very irregular reflections of the light, from

the paint on the inside of them, as from the vast contrast into which the eye is thrown, when it removes from the reflected light, that is, from an extreme of brightness to gloominess and obscurity. In the place of these, I would recommend a conical shade of white paper, moderately thick; this will throw a strong steady light down on the book, &c. it will preserve the eye from the luminous brightness and glare of the candle, and not darken the room too much. Here I cannot refrain from observing, that the clear white light of Argand's lamps must be very prejudicial to the sight; there are purposes to which they may be applied with advantage, but then it should be where their light is modified before it reaches the eye.

Of Spectacles with coloured Glasses.

It may be more difficult to decide upon the merit of spectacles with coloured glass, than of those with visuals; yet upon the whole, there is reason to think, that they are rather of dis-service than of any use to the eye, and that the grounds upon which it has been supposed that they would be advantageous to the sight, are weak and fallacious.

Green

Green glaſſes have been recommended on two accounts, firſt, becauſe green is univerſally allowed to be one of the pleaſanteſt colours we look at, and is found to ſtrengthen, comfort, and preſerve the ſight: ſecondly, as they are ſuppoſed to weaken the impreſſion of the rays of light on the retina, and therefore to be well adapted to thoſe whoſe eyes are weak and tender.

To the firſt reaſon, it may be ſufficient to anſwer, that though green is a pleaſant colour to look at, it is by no means ſo to look through; for all objects, when viewed through green glaſs, appear of a muddy yellow, tinged by a gloomy green; they are, however, not only unpleaſant, but there are circumſtances attending the uſe of them, which make it highly probable, that they are prejudicial to the ſight, and have not the tendency which is generally attributed to them, of leſſening the action of the rays of light on the eye.

After looking at the ſun for a ſhort time, ſhut your eyes, and you will, for ſome time after they have been ſhut, continue to ſee his image; but it's brightneſs will gradually diminiſh, aſſuming, ſucceſſively, colours leſs and leſs bright and lively, being firſt red, afterwards yellow, then

green, blue, and laſtly, violet; now theſe colours are attributed to the violent agitation excited in the retina, by the rays of light; the re-action and vibrations produce the ſenſation of colour, the ſtrongeſt thoſe of red, the weaker thoſe of yellow, &c. Something very ſimilar to this happens to moſt people, on their firſt wearing green glaſſes, for on taking them off, they generally find white objects tinged with red; a clear and ſufficient proof, that they are not favourable to the eye.

Further, unleſs they are continually wore, the contraſt between the object ſeen through them, and ſeen without them, muſt be diſadvantageous in it's effects; as contrary to that uniformity, which we have already obſerved, to be ſo neceſſary to the preſervation of the eyes.

But there is a ſtill greater inconvenience; the eye, by conſtant uſe, ſo habituates itſelf to them, as not to be able to ſee with eaſe in ſpectacles of another colour: now as the eye grows flatter, it wants glaſſes of a greater convexity; but as the convexity increaſes, the green glaſſes become more opake, and thus leſs fit for viſion, affording leaſt aſſiſtance when the eye wants it moſt.

Of Reading-Glasses.

Though the effects of time are the certain and inevitable portion of all, who live to an advanced age, and are neither to be retarded by riches, nor prevented by wisdom; yet such are the weaknesses of the human mind, and such the partialities of self-love, that we all endeavour to conceal, from ourselves and others, the approaches of age; and no one likes to appear as hastening to that bourne from which none have returned.

These propensities give rise to a variety of artifices, by which each individual endeavours to hide from himself and others, what no artifice can conceal, and which every one can discover, in all but himself; but then, these endeavours often contribute to hasten the evils they are meant to conceal. Opticians have daily experience of the truth of these observations, and they are in no instance more fully verified, than in the preference given by many to reading-glasses, (under whatever pretext it may be covered,) merely because they think, that the decay of their

ſight, and their advances in age, are leſs conſpicuous by uſing a reading-glaſs than ſpectacles.

It is evident, that the axes of the eyes ought not in any caſe to be ſtrained, but that they ſhould be left at liberty, to follow the direction they receive from the muſcles of the eye; but this is not the caſe when a reading-glaſs is uſed; for the eyes, in endeavouring to ſee by it, are conſiderably ſtrained, and in a ſhort time much fatigued: but there is another objection to the uſe of reading-glaſſes, which ariſes from the unſteadineſs of the hand, and the motion of the head, which occaſion a perpetual motion of the glaſſes, for the eye endeavours to conform itſelf to each change, and this tender organ is thereby kept in continual agitation: to theſe evils we may add, the dazzling glare and irregular reflection from the ſurface of the glaſs, which ſo weaken the eyes, that thoſe who accuſtom themſelves to a reading-glaſs, are in a ſhort time obliged to take to ſpectacles, and to uſe them much older than they otherwiſe would have done.

To this it may be added, that ſpectacles are preferable, not only as more conformable to the nature and action of the eye, but they are alſo more

more convenient; the ſpace between the face and the object is left open and free, and they are moved inſenſibly by the natural motion of the head; they alſo ſhew objects more clear and more diſtinct than a broad lens, becauſe their glaſſes are thinner, and placed exactly before each eye.

To obviate ſome of theſe inconveniences, my father contrived a kind of ſubſtitute for ſpectacles, which are convenient for looking at any occaſional object, and not injurious to the eyes; this kind is repreſented at fig. 8. In theſe both eyes are uſed at once, without any effort; by being held near the eye, the irregular reflections are avoided, and they are at the ſame time rendered ſteady, by a ſlight preſſure of the middle bar on the noſe.

To ſuit a given Eye with proper Spectacles, or to enable a given Eye to ſee diſtinctly at a certain Diſtance.

For this purpoſe, a rule is delivered by optical writers, which, though it is good in theory, is liable to ſeveral exceptions in practice, particularly as by exactly adhering to it, they would generally chooſe glaſſes of too great a magnifying power;

power; but as notwithſtanding this defect, the data it requires may give uſeful information to the optician, for furniſhing glaſſes to thoſe who live in the country, we ſhall inſert it here.

Rule.

To find a convex lens ſuited to a long-ſighted eye, multiply the diſtance at which the perſon ſees diſtinctly, by the diſtance at which it is deſirable he ſhould ſee with the ſpectacles, and divide the product, by the difference between the two aforeſaid diſtances, the reſult is the focus required.

Thoſe who, uſing ſpectacles, live at a diſtance from town, and think thoſe they have are not accommodated to their ſight, may receive information whether they can be better ſuited or not, by ſending any ſkilful optician the focus of the glaſſes in their ſpectacles, and the diſtance at which with them they can read a ſmall print.

To find the focus of a convex lens, or ſpectacle eye, firſt by the ſun's image, place the lens, ſo that it's axis may be toward the ſun; then holding a paper behind it, the burning point or where the ſun's image is ſmalleſt, and where the

limb

limb is moſt diſtinct, is the focus of the lens, and the diſtance from this point to the lens is the diſtance required.

Or, ſecondly, fix a piece of paper on the ſide of a room, exactly facing a window, and remove the lens from this, till the images of the moſt diſtant objects out of doors are diſtinct, then the diſtance between the lens and the paper is the required focal length: the images will be brighter the leſs the quantity of light is admitted into the room, except what is directly oppoſed to the lens.

The foregoing methods are ſufficiently accurate for common ſpectacles and reading-glaſſes, but not for lenſes of a long focus.

Of Couched Eyes.

With the diſeaſes of the eye, this ſmall eſſay has no concern; they have been already well and ably conſidered by profeſſional men; and it is ſcarce neceſſary to obſerve, that in anatomical knowledge, and in the practical operations of ſurgery, England now claims a juſt pre-eminence over other nations.

But

But among the various diſeaſes of this organ, there is one in which, after the ſurgeon has quitted the patient, glaſſes are neceſſary, to give effect to the operation, and a comfortable ſight of objects to the perſon relieved. This diſeaſe is the cataract, a diſorder affecting the cryſtalline humour of the eye; when the opacity is confirmed, this humour becomes ſo opake, as ſcarcely to admit any rays of light, and prevents their producing their ordinary effects, and conſequently no image of any object is formed, though the retina, and other organs of ſight, are in perfect order. There is no diſorder more deplorable in it's nature and conſequences; deſtructive of the ſight, often beyond the reach of remedy: the hand of the operator is the only hope, and his efforts are ſometimes unſucceſsful.

The cauſe of this diſorder is ſeldom known. Sometimes it has been thought to be brought on by frequent inſpection of the ſun, and ſometimes by looking too long and too often at a bright fire. In early ſtages of the diſeaſe it has been thought to be removed by medicine.* Of the various

* Baron de Wenzel, in his Treatiſe on the Cataract, denies that any medicine has power to diſſipate the opake cryſtalline. Mr. Ware, in his tranſlation of this work, aſſents

various remedies that have been uſed for this purpoſe, the electrical ſtream is ſuppoſed by many to be the beſt, on account of it's powerful diſcutient properties.

The aſſiſtance the eye receives from the ſurgeon is either by a depreſſion of the cryſtalline below

aſſents to the truth of the Baron's obſervation, ſo far as is at preſent known; but adds, that many caſes have occurred, under his own inſpection, which prove that the powers of nature are often ſufficient for this purpoſe. Thoſe opacities in particular which are produced by external violence, he has repeatedly ſeen diſſipated in a ſhort ſpace of time, when no other parts of the eye have been hurt; and in general, in caſes of this deſcription, the cryſtalline humour has been diſſolved; which has been demonſtrated, by the benefit the patient has afterwards derived from adopting the uſe of deeply convex glaſſes. Mr. Ware adds, that inſtances are not wanting, in which cataracts, which were formed without any violence, have been ſuddenly diſſipated, in conſequence of an accidental blow on the eye. For theſe reaſons he entertains a hope, that means may hereafter be diſcovered, by which an opake cryſtalline may be rendered tranſparent, without the performance of any operation whatever. The remedies which have appeared to Mr. Ware more effectual than others, in theſe caſes, have been the application to the eye itſelf of one or two drops of æther, once or twice in the courſe of the day, and the occaſional rubbing of the eye over the lid, with the point of the finger, firſt moiſtened with a weak volatile or mercurial liniment. See Ware's tranſlation of Wenzel's Treatiſe on the Cataract, page 13.

below the pupil, or extracting the cataract. But as the density of the vitreous humour, which supplies the place of the crystalline, is less, the rays of light will be less refracted, and not meet at the retina, but at some distance behind it; the sight will therefore be imperfect, except the eye be assisted with a proper convex glass. There is a circumstance attending couched eyes, which fully evinces that the change made in our eyes, to accommodate them to the distances of objects, must be principally attributed to the crystalline humour; namely, that one focus is seldom sufficient to enable those who have undergone this operation, to see objects at different distances. They generally require two pair of spectacles, one for near, the other for more distant objects. The foci that are used lie between 6 and 1 ½ inches.

It is not adviseable to use glasses too soon after the operation; for while the eyes are in a debilitated state, all exertions are not only improper, but also very prejudicial.

Of the Short-sighted.

In this defect of the eyes, the images of objects at an ordinary distance unite before they arrive

at

at the retina, and conſequently the images formed thereon are confuſed and indiſtinct. This effect is produced either by too great a convexity in the cornea and cryſtalline, or too great a refractive power in the humours of the eye; or the retina may be placed too far; or it may ariſe from a concurrence of all theſe circumſtances.

Thoſe who are ſhort-ſighted can diſtinguiſh ſmaller objects, and ſee clearly a given ſmall object with leſs light than other people; the reaſon is evident, for the nearer the object is, the more light enters the pupil; being alſo more denſe, it's action is more powerful on the retina; hence the ſhort-ſighted can read a ſmall print by moon-ſhine, or in the twilight, when a common eye can ſcarce diſtinguiſh one letter from another.

In a ſtrong light they can ſee a little farther than they do when it is weak; the ſtrength of the light cauſes the pupil of their eyes to contract, and thus removes in ſome degree the indiſtinctneſs of the objects. Upon the ſame principle we may account for the ſhort-ſighted ſo often partly ſhutting their eyelids, from whence they were formerly denominated *myopes*; by this means, they confine the baſes of the pencils of rays which

which iſſue from the points of an object, and thus contract the circle of diſſipation, and leſſen the indiſtinctneſs of viſion: hence they alſo ſee objects more diſtinctly through a ſmall hole, as that made by a pin in a card.

It is a common obſervation, that the ſhort-ſighted do in general prefer a ſmall print to a large one, and that they uſually write a ſmall hand; for by the proximity the letters are magnified, and, being ſmall, they take in a greater number at one view; they hold the book they are reading in generally inclined to one ſide, in order to attain a greater degree of illumination. As they can only ſee diſtinctly objects that are near, they are obliged, by a ſtrong effort of the mind, to cauſe the axes of the eyes to converge; this effort being painful, forces them often to turn away one of their eyes, which producing double viſion, they are obliged to ſhut it. When they hold a book directly before their eyes, the picture will fall upon the middle of the retina, but if they hold it obliquely it will fall upon the ſide of the retina; now the middle of the retina is further from the fore part of the eye than the ſide of it is. Therefore though the picture be ſo near to the fore part of the eye as to be confuſed

fused if it fall upon the middle, it may be distinct when it falls upon the side.

As those who are very short-sighted do not perceive the motion of the eyes and features, they seldom look attentively at those with whom they are conversing: it is from this circumstance that Pliny terms the prominent-eyed *hebetiores*; not that this defect in sight impairs genius, or lessens the powers of the mind; but as it deprives them of the rapid communications that are made by the eye, it apparently lessens that vivacity of conception, which always accompanies a vigorous mind.

Happily for the short-sighted, the principal inconveniences of their sight may be remedied by the use of concave glasses; by their assistance, those whose sphere of distinct vision scarce extended beyond their arm, are enabled to distinguish, very satisfactorily, objects at a considerable distance; the concave lens produces distinct vision, by causing the rays to diverge more, and unite at the retina, instead of meeting before they reach the bottom of the eye.

In the choice of glasses for the short-sighted, no rules can be laid down; it is a defect that has

no connection with age, no stated progression that can be a foundation to guide the optician, or lead him to recommend one glass in preference to another; the whole must depend on the observation of the short-sighted themselves, who, by trying glasses of different degrees of concavity, will soon find out that whose effects are most advantageous, producing distinct vision at different distances.

If the short-sighted person is so far removed from an optician, as not to have an opportunity of trying a variety of lenses, he may be nearly suited, by sending to him the greatest distance at which, with his naked eye, he can see distinctly; he will, by the following rule, be enabled to suit him with tolerable exactness.

Multiply the distance at which the short-sighted person sees distinctly with his naked eye, by the distance at which it is required he should see distinctly by a concave glass, and divide the product by the difference between the aforesaid distances: if the required distance be very remote, the glasses must be of that radius at which they see distinctly with their naked eyes.

The benefit the short-sighted receive from

concave

concave glasses, is not so great as the long-sighted find by a convex lens; for an object is not only magnified, but the eye receives also a larger pencil of light from each visible point, because the rays enter less diverging: whereas the concave not only diminishes the object in size, but it lessens also the quantity of light, as it renders the rays more diverging; consequently the short-sighted do not see remote objects, unless they are very large and bright, so well through a concave lens as theory promises: for the chief impediment to a distinct view of remote objects, is their want of light and magnitude, but both of these a concave lens increases.

It is generally supposed, that the short-sighted become less so as they advance in years, as the natural shrinking and decay in the humours of the eye lessen it's convexity, and thus adapt it better for viewing of distant objects: but among the great number of short-sighted that I have accommodated with glasses, I have ever found the reverse of this theory to be true, and the eyes of the myopes never required glasses less concave, but generally more concave as they grew older, to enable them to see at the same distance.

Further, the effects of habit, which are in most

cafes very powerful, but peculiarly fo in the affections of the eye, have a natural tendency to increafe the defect of the myopes, for by frequently looking clofe to objects, in order to fee them diftinctly, they would make themfelves near-fighted, though their eyes were naturally the reverfe; hence we often find, that watch-makers, engravers, and ftudious perfons, often bring on this defect. By reading or working at as great a diftance as poffible, and often looking at remote objects, the degree of fhort-fightednefs may be much leffened. As children in general read much nearer than grown perfons, if they are fuffered to indulge this propenfity, they become naturally fhort-fighted.

I have found it neceffary, in fome inftances, to give convex glaffes to the fhort-fighted, when very far advanced in age, not becaufe their eyes were grown lefs convex, but to give them more light, and counteract an extreme contraction of the pupil.

Great as are the difadvantages of the fhort-fighted, they are lefs, perhaps, with refpect to diftant objects, than is generally imagined; they fee the brighter ftars and planets, nearly as well as other people. They are prevented indeed from

from diſtinguiſhing beyond a certain ſmall diſtance, the ſmall parts of an object which are very viſible to another; thus they cannot diſtinguiſh the features of a face acroſs a room, and as objects are generally diſcriminated by their minuter parts, their diſadvantage in viewing objects at a moderate diſtance is very evident. But though ſuch a perſon cannot diſcern the minutiæ of objects, unleſs they are very large and very near him; yet he can perceive any object in the groſs, at a conſiderable diſtance, if it be not too ſmall: thus he may perceive a man at the diſtance of ſeveral paces, but muſt advance within one or two, before he can determine who he is, or call him by his name; he will ſee a large tree much further, and from experience in ſuch caſes, will perceive, that a large obſcure object at a great diſtance is an houſe, to the ſurprize of his friends who are acquainted with the nature of his ſight. On theſe principles, we may eaſily account for the apparent paradox of the pur-blind, or thoſe who can ſcarcely ſee a ſmall object at arm's length yet diſcovering thoſe that are very remote.

Of a Crepuſcular or Twilight Blindneſs.

Thoſe that are afflicted with this complaint, have their ſight dull and confuſed in the even-

ing and morning, diſcerning objects very imperfectly at the ſame time and place: while thoſe who are bleſſed with perfect viſion, ſee them diſtinctly.

Many years ago, this diſorder was epidemical in the neighbourhood of Montpellier, eſpecially in towns contiguous to a river, and among the ſoldiers doing duty as centinels, expoſed to the damps and fogs of the night ſeaſon; and it was judged to proceed from a ſuperfluous ſerum in the maſs of blood, which affected and relaxed the organs of viſion; the pupil of the eye was much dilated, and the ſenſibility of the retina leſſened.

Boerhaave mentions a variety of this diſorder, which aroſe from an immoveable ſtructure of the pupil; it did not, like the other, give way to medicine; it is probable, that in both caſes, electricity would be of great uſe.

Of Meridian Blindneſs.

„ Thoſe who are afflicted with this diſorder, can diſcern objects in the night, but are unable to diſtinguiſh them in the day-time.

Boerhaave enumerates two varieties of this diſorder. The firſt proceeds from an opake round ſpot; or partial cataract in the middle of the cryſtalline, exactly behind, but ſomewhat ſmaller than the pupil; during the day, the pupil is ſo contracted as to admit no rays of light, but what fall upon the opake ſpot, which, therefore, prevents the formation of any image upon the retina; but in the evening, the pupil is ſo dilated, as to permit ſuch a quantity of light as will anſwer the purpoſes of viſion.

This variety may be removed by the electric fluid; or if that does not ſucceed, by the couching needle.

The ſecond variety ariſes from ſo extreme a ſenſibility of the retina, that it entirely cloſes the pupil of the eye; this ſpecies generally yields to antiphlogiſtic remedies.

Of an abſolute Dulneſs of Sight.

This kind of ſight has been generally confounded with long-ſightedneſs, but has lately been ranked, by ſome anatomical writers, under a diſtinct head.

Both the ſhort and long-ſighted, in certain poſitions, and at certain diſtances, ſee objects diſtinctly, and their ſight is not confuſed but relatively, with reſpect to other diſtances, poſitions, and times; but in the affection of the eye now under conſideration, there is an abſolute dulneſs of ſight, in all places, at all times, and in all ſituations.

It ſeems to depend on a want of ſenſibility in the retina, and happens more eſpecially to thoſe who have abuſed their eyes: it is a diſeaſe to which, by common people, a variety of cauſes are aſſigned.

The principal ſymptoms are frequent variations in the boundaries of diſtinct viſion; objects, when attentively conſidered, appear confuſed, the characters of books ſeem to be doubled, moved, and decuſſated, the eyes being ſoon fatigued, they are frequently obliged to rub and ſhut them, and the pupil is ſcarcely moveable, even on a ſudden tranſition from darkneſs to light.

Various are the remedies preſcribed by oculiſts for this diſorder, ſome praiſing ſpirituous reſolvents, while others extol cold water; but all agree in recommending the uſe of ſpectacles, with double

ble convex glaſſes; for as by theſe more rays of light are collected, and a ſtronger impreſſion made on the retina, a conſiderable degree of diſtinctneſs is promoted.

Electricity has been recommended with ſucceſs, the eye has been in part reſtored, and the pupil recovered it's power of contracting and dilating.*

Among

* The following caſe, which fully evinces the powers of electricity in diſeaſes of the eye, was communicated to me by my very ingenious friend, John Birch, Eſq. ſurgeon of St. Thomas's hoſpital.

In the year 1786, Ann Bone, aged 57, was admitted into St. Thomas's hoſpital, under the care of Mr. Chandler, totally blind. After the uſual remedies had been unſucceſsfully tried, ſhe was ſent to the electrical chamber, where Mr. Whitelocke, now ſurgeon at Ramſbury, had the care of the machine, under the direction of Mr. Birch. The ſhocks were paſſed through the globe of the right eye, and the ſight of that eye was recovered in one week's experiment. The woman was deſirous of leaving the hoſpital, content with the recovery of the ſight of one eye, and fearful of the pain ſhe experienced from the ſhock; but a report of the caſe being made to the ſurgeons, Mr. Birch directed the electric fluid from a wooden point only, to be poured into the other eye, which perfectly reſtored the ſight of it, though not in ſo ſhort a time. At the end of the

Among the leſſer maladies of the eyes, the moſt common is a redundance of water, or of a watery humour, which diſturbs and impairs the ſight. When the eye is full of water, letters appear confuſed, and no ſmall object is ſeen diſtinctly. In this caſe it is uſual to have recourſe to ſpectacles; but the author of an excellent little tract on the fabric of the eyes, ſays, that in this diſorder it is the glaſs, not the form, that is neceſſary; and that when it is the extreme moiſture of the ball of the eye alone, which makes objects appear confuſed, they will be rendered diſtinct, by placing a piece of thick clear glaſs between the eye and the object: he, therefore, adviſes the uſe of a pair of ſpectacles, of plain thick coach-window glaſs, without any convexity: the uſe of theſe will forward the cure, which

the month ſhe was diſcharged from the hoſpital, perfectly cured, able to read, work, and tell the time by a watch.

Several ſimilar caſes have ſince happened, with which, perhaps, the public may, in time, be made acquainted; though moſt of them are caſes of the gutta ſerena, the cataract not having been found to yield to electricity. See a remarkable caſe of the gutta ſerena, accompanied with a paralyſis of the eye-lids, which was perfectly cured by an electric application in three days, annexed to Mr. Ware's Remarks on the ophthalmy, pſorophthalmy, and purulent eye, page 151, ſecond edition, printed for Dilly, 1787.

which will ſoon be effected by an application of the proper remedies, care being taken at the ſame time to avoid extremes of light.

Of Squinting.

I heſitated long, whether I ſhould ſay any thing concerning this affection of the eyes, but was at laſt determined, by conſidering, that this eſſay might paſs into many hands, who would probably never ſee thoſe philoſophical and medical treatiſes, in which this ſubject has been particularly handled; and that I might, therefore, be a mean of communicating uſeful knowledge to thoſe whom it would otherwiſe never reach.

It muſt, however, be confeſſed, that after all that has been written upon this ſubject, we are advanced but a very little way; thoſe who have had ſkill to make proper obſervations, have wanted opportunity, and thoſe who have had opportunity, have been deficient either in ſkill or attention.

Before we advert to the unpleaſing diſpoſition of the eyes, termed *ſquinting*, it will be proper to conſider that curious phænomenon of viſion, by

by which we are enabled to ſee objects ſingle with two eyes; for two pictures of the object are formed, one on each retina, each picture exhibits the object to us in a certain direction, yet we in general perceive only one object. Whenever we look attentively at any object, the axes of both eyes are directed towards it, and we are ſo accuſtomed to turn both eyes towards the ſame place, that if one eye be ſhut, it's motion will follow that of the other. This concurring motion has been one of the reaſons aſſigned, why an object ſeen with both eyes appears ſingle; but this, like moſt other ſolutions of this phænomenon, is very unſatisfactory, for the eye ſees not the concurrence of theſe imaginary axes: whatever be the cauſe, we are aſſured of the fact, that when both eyes look at the ſame object, the mind ſees that object ſingle.

Dr. Reid, who has conſidered this ſubject* with much attention, reſolves the whole into a law of nature, laying it down as a general fact, or phænomenon of viſion, that in perfect human eyes, the centers of the two retinæ correſpond and harmonize with one another, and that every other point in one retina, correſponds with that point

* Reid's Inquiry into the Human Mind. p. 282.

point which is ſimilarly ſituated in the other. When the pictures fall, therefore, on correſponding points of the two retinæ, one object only will be ſeen, though there ſhould be really two; and the pictures falling upon the points of the retinæ that do not correſpond, will occaſion two viſible appearances, although there be but one object. Pictures upon correſponding points of each retina, raiſe in the mind a ſenſation of the ſame appearance, as if they had fallen upon the ſame point of one; while pictures falling upon points of the two retinæ, which do not correſpond, give the mind the idea of two diſtinct objects.

If we diſtort unnaturally our eyes from their parallel direction, or if, while we direct the axes of the two eyes to one point, and at the ſame time exert our attention, which is alſo unnatural, on another object, either much nearer, or much further, in theſe caſes we ſee one object double, or two confounded in one.

The laws of viſion, in the human conſtitution, are wiſely adapted to the natural uſe of the eyes, but not to that which is unnatural; when we are obedient to the laws of order, as manifeſted in nature, we ſee objects properly, but have falſe

appearances preſented to us, when we uſe them in an unnatural manner. No part of the human conſtitution is more to be admired, than that whereby we acquire habits which are found to be uſeful, without any deſign or intention.

Squinting is attributed to a variety of cauſes; in many inſtances, it is undoubtedly owing to a prevailing principle of human action, habit induced by imitation: at other times to habit, brought on from the peculiar circumſtance in which the eye happens to be placed.

A new born infant is incapable of fixing his eyes on any object, he moves one without moving the other,* or moving it in a contrary direction, rolling them about, being unable to diſcriminate one object from another; but as the body grows ſtronger, the eye becomes fortified and capable of obeying the action, and receives the impreſſions of the mind, which now directs the optical axes towards the ſame point, which direction becomes afterwards ſo natural, that in proceſs of time it can ſcarce be altered even by the efforts of the will.

But

* This is denied by Reid, on the authority of his own obſervation on his own children, and from the information of others.

But while the powers of the body are weak, if the infant be ſo placed in it's bed, or cradle, as to view the light or any agreeable object, from one ſide only, it will probably learn to ſquint; for though at firſt he may diſcern the object with both eyes, yet as this requires ſome exertion, and that perhaps rather painful, he ſoon relaxes of his labour, and turns only that eye which is near the object, from which, if often practiſed, he forms the habit of moving his eyes differently; the ſame aptneſs to turn the eyes in contrary directions may be brought on, by often preſenting to them, at the ſame inſtant, a variety of objects.

A cold in the head, a lowneſs of ſpirits, or a continued exertion or poring of the eyes, will often occaſion thoſe to ſquint, that are not accuſtomed to do it at other times. This is probably occaſioned by a ſoreneſs or tenderneſs of the retina, which makes the impreſſions of light ſo offenſive, that the eyes are forced into an unnatural direction; that by ſeeing obſcurely, pain may be avoided: or it may be an affection of the muſcles of the eye. This diſtemper may be cured, by uſing flat green glaſſes, or any other contrivance that will leſſen the light. This ſoreneſs may alſo be a fixed diſtemper in one eye;

the

the perſon will then turn it on one ſide, not that he may ſee better, but to avoid ſeeing with it at all.

This defect may be produced by a ſpaſm in the muſcles that move the eye, or by ſome of them being either too ſhort or too long, too rigid or too lax. If, by any of theſe means, the natural equilibrium be deſtroyed, the eye will be turned too much one way; among theſe cauſes, ſome are beyond, and others within, the reach of medicine: of the various tonics that may be applied, electricity will probably be found the moſt powerful, and moſt efficacious.

An oblique poſition of the cryſtalline, or the cornea, will occaſion ſquinting; in either of theſe caſes, no aſſiſtance can be derived from art. The object to which the eye is directed is not diſtinctly ſeen, becauſe it's image does not fall upon thoſe parts of the retina that are beſt ſuited to anſwer the purpoſes of viſion.

One part of the retina is generally ſuppoſed to be more ſenſible than another, and that we turn our eyes, ſo that this part may receive the impreſſions of the light; but if this part be awry

in one or both eyes, the perſon will neceſſarily ſquint.

Dr. Jurin, Mr. Buffon, and Dr. Reid have ſhewn, that the greateſt number of thoſe that ſquint have very indiſtinct viſion with one eye. Indeed, M. Buffon aſſerts, that the true and general cauſe of this diſeaſe is an inequality in the limits of diſtinct viſion in the two eyes; when one eye is more feeble than the other, we do not direct it towards the object, but make uſe of that which is ſtronger. Dr. Jurin obſerves, that thoſe who ſquint, and ſee with both eyes, never at the ſame inſtant ſee the ſame object with both eyes; for when one eye is turned directly towards an object, the other is drawn ſo cloſe to the noſe, that to it the object is inviſible. In ſome ſquinting eyes he obſerved the diverging eye to be drawn under the upper eyelid, while the other was directed to the object.

Dr. Reid recommends eleven ſubjects of inquiry to thoſe who may meet with caſes of this diſorder, as neceſſary not only for giving us a true inſight into this ſubject, but alſo for laying the foundation of a rational mode of cure; theſe I ſhall therefore ſubjoin.*

* Reid on the Human Mind.

1. We ought to inquire whether the ſquinting perſon ſees equally well with both eyes? and if there be a defect in one, the nature and degree of that defect ſhould be inveſtigated. The obſerver muſt not, in this caſe, rely upon the teſtimony of the patient; but muſt make ſuch experiments as will be proper for drawing a juſt concluſion. In all the ſucceeding heads of inquiry, the patient is ſuppoſed to ſee ſo well at leaſt with both eyes, as to be able to read with either, when the other is covered.

2. When one eye is covered, we muſt ſee whether the other is turned directly towards the object. If the ſquinting eye turns aſide from the object when the other is covered, it would prove that in that inſtance De la Hire's famous hypotheſis was true. In all the caſes, however, that have been tried by Meſſ. Jurin, Porterfield, and Reid, the contrary has taken place, and the axis of the ſquinting eye was turned directly towards the object, when the other was covered.

3. We ought to ſee whether the axes of the two eyes follow each other, ſo as to have always the ſame inclination, or form the ſame angle, when the perſon looks to the right or to the left, upward or downward, or ſtrait forward; this will

will determine whether a ſquint be owing to any affection of the muſcles. In the following heads of inquiry; the inclination of the axes of the eyes is ſuppoſed to be always the ſame.

4. Whether the patient ſees an object ſingle or double.

There is, probably, always a greater or leſs diſtortion of the eyes where there is double viſion; yet it is certain that there is not always double viſion where there is a ſquint; there are, perhaps, no inſtances where double viſion has laſted any length of time. In the following inquiry we ſhall take it for granted, that the ſquinting perſon ſees objects ſingle.

5. Our next inquiry ſhould be, whether the object is ſeen with both eyes at the ſame time, or only with that eye whoſe axis is directed towards it.

Moſt writers before Dr. Jurin, took it for granted, that thoſe who ſquint ſee objects ſingle with both eyes at the ſame time: it is an opinion unſupported by facts, and the truth of it denied by Jurin. It is very eaſy, in any particular inſtance, to decide the queſtion. While the perſon

that ſquints looks ſteadily at any object, let the obſerver carefully remark the direction of both eyes, and obſerve their motions; and let an opake body be placed between the object and each eye ſucceſſively. If the patient, notwithſtanding this interpoſition, and without changing the direction of his eyes, continues to ſee the object all the time, we may fairly conclude that he ſaw it with both eyes at once. But if the interpoſition of the opake body between one eye and the object makes it diſappear, then we may be as ſure that it is ſeen by that eye only.

In the two next articles we ſuppoſe the firſt to happen, according to the generally received hypotheſis.

6. On this ſuppoſition, it ought to be inquired whether the patient ſees an object double in thoſe caſes, where it appears double alſo to thoſe who do not ſquint.

For this purpoſe, let him place a candle at the diſtance of ten feet, and holding his finger at arm's length between him and the candle, let him obſerve when he looks at the candle, whether he ſees his finger with both eyes, and whether he ſees it ſingle or double; and when he looks at his finger, let him obſerve whether he

ſees

ſees the candle with both eyes, and whether it appears ſingle or double.

If the patient is found to ſee objects ſingle with two eyes, not only in the caſes wherein they appear ſingle, but alſo where they appear double to other men, we may conclude, that his ſingle viſion does not ariſe from correſpondent points in the retinæ of his eyes, and that the laws of viſion are different in him, from what they are in the reſt of mankind.

If, on the other hand, he ſees objects double in thoſe caſes wherein they appear double to others, we muſt conclude that he has correſponding points in the retinæ of his eyes, but that they are ſituated unnaturally. If the common hypotheſis be true, that one who ſquints ſees an object with both eyes at the ſame time, and yet ſees it ſingle, the ſquint will probably be of the kind deſcribed in this article; and we may conclude, that if a perſon, affected with ſuch a ſquint as we have here ſuppoſed, could be brought to the habit of looking ſtrait, it would be highly prejudicial to the ſight: for he would then ſee every thing double which he ſaw with both eyes at the ſame time, and objects diſtant from each other would be confounded together; his eyes are made

for ſquinting, and the cure would be worſe than the diſeaſe, as it is far better to ſquint, than to purchaſe the cure, by the loſs of perfect and diſtinct viſion.

8. We may after theſe trials return to the hypotheſis of Dr. Jurin, and ſuppoſe, that the patient when he ſaw objects ſingle, notwithſtanding his ſquint, was found, upon trial, to have ſeen them only with one eye.

The patient muſt now be adviſed by repeated efforts to leſſen his ſquint, and to bring the axes of his eyes nearer to a parallel direction; we have a power of making ſmall variations in the inclination of the optic axes, and this power may be greatly increaſed by exerciſe, by perſeverance, and patience. If the practice is begun while the patient is young, he will probably ſoon learn to direct both his eyes to one object. When this power is acquired, it will be eaſy to determine, whether the center of the retinæ, and points ſimilarly ſituated with reſpect to theſe centers, correſpond as in other men.

9. Let us now ſuppoſe this to be the caſe, and that he ſees an object ſingle with both eyes, when the axes of both are directed to it.

It

It will then be his businefs to acquire the habit of looking ftrait, as he will thereby not only remove a difagreeable deformity, but confiderably improve his fight.

10. As the cafe mentioned in the ninth article is not merely hypothetical, but founded on abfolute fact, it will be neceffary further to inquire, how it happens that fuch a perfon fees an object at which he is looking only with one eye, when both are open?

To elucidate this queftion, we muft again go to experiment, and obferve, firft, Whether our patient, when he looks at an object, does not draw the diverging eye fo clofe to the nofe, that it can have no diftinct images? or fecondly, Whether the pupil of the diverging eye is not covered wholly, or in part, by the upper eyelid? thirdly, Whether the diverging eye is not fo directed, that the picture of the object falls upon that part of the retina, where the optic nerve enters, and where there is no vifion? This is probably the cafe in a fquint, where the axes of the eyes converge fo, as to meet about fix inches before the nofe.

11. In the laft place we fhould inquire, whe-

ther the perſon has any diſtinct viſion at all with the diverging eye, at the time he is looking at an object with the other; for though the perſon may be able to read with the diverging eye, when the other is covered, yet when both are open it may have no diſtinct viſion.

The foregoing inquiries are much eaſier in theory than practice, and for inſuring ſucceſs, ſome qualifications of mind are neceſſary in the patient, which are not always to be met with; but a due attention to them, where there is opportunity, will ſoon furniſh us with more important facts than we are at preſent acquainted with: by theſe facts vain theory will be exploded, and our knowledge of the laws of nature, with regard to the nobleſt of our ſenſes, enlarged.

Of the Method of Cure.

We ſuppoſe the preceding inquiries to have been made, previous to any attempts towards a cure; if, in conſequence of theſe, we find that the cure will not be prejudicial to the patient's ſight, we may proceed to try any of the following methods; the firſt is that propoſed by Dr. Jurin. "When the patient is of an age capable of attending to the following directions, place him

him directly before you, and let him close the undistorted eye, and look at you with the other; when you find the axis of this eye fixed directly upon you, bid him endeavour to keep it in that situation, and open his other eye; you will now perceive the distorted eye turn away from you towards the nose, and the axis of the other eye will be pointed towards you. By patience and repeated trials, he will be able to keep his distorted eye fixed upon you, at least for a little time after the other is opened, and when you have brought him to keep the axes of both eyes fixed upon you, while you stand directly before him, it will be time to change his posture, and to place him a little on one side of you, and then on the other, continuing the same practice; when he can in all situations perfectly and readily turn the axes of both eyes towards you, the cure is effected; this will be forwarded by his frequently practising before a mirror, and by having a friend always at hand, to observe and admonish him when he squints.

Messrs. Buffon, Reid, and Darwin, concur in recommending the patient to cover the good eye, as the most effectual and natural method of cure, as by frequent use, the sight of the weak eye is strengthened, and acquires a habit of turning

to

to the objects which the patient wishes to see; and the better eye by losing something in this respect facilitates greatly the cure; the inequalities in the eyes should, however, be first well ascertained, because this method will not succeed if there is too great a difference. M. Buffon says, that if the eye that squints be turned towards the temples, there is seldom any great inequality between them, and that in this case, the disorder arising only from a vicious habit, he has known the cure to be completed, by covering the good eye for a fortnight only: it is necessary to cover the good eye for some time, in order to exercise and strengthen the bad eye, that a proper judgment may be formed of the possibility of the cure.

In the 68th vol. of the Philosophical Transactions, Dr. Darwin has given an account, of which the following is an extract, of a very curious and confirmed case of squinting, and of the method he used for curing it.

The patient was a boy five years old, who viewed every object that was presented to him with but one eye at a time.

If the object was presented on the right side, he

he viewed it with his left eye; if it was presented on the left, he viewed it with the right eye.

He turned the pupil of that eye which was on the same side with the object, in such a direction, that the image of the object might fall upon that part of the bottom of the eye, where the optic nerve enters it.

When an object was held directly before him, he turned his head a little on one side, and observed it but with one eye, namely, that most distant from the object, and when he became tired of observing it with that eye, he turned his head the contrary way, and observed it with equal facility with the other eye, but never turned the axes of both eyes towards it at the same time.

He saw letters which were written on bits of paper, so as to name them with equal ease, and at equal distances, with one eye as the other.

There was no perceptible difference in the diameter of the pupils, or their degree of contractability,

tractability, after having covered his eyes from the light.

The foregoing obſervations were carefully made, by writing ſingle letters on ſhreds of paper, and laying wagers with the child, that he could not read them when they were preſented at certain diſtances, and in certain directions.

As from theſe circumſtances it appeared that there was no defect in either eye, and that the diſeaſe was ſimply a depraved habit, there was great room for hopes of ſucceſs in the cure.

For this purpoſe a proper gnomon was made and fixed to a cap, and when this artificial noſe was placed over the real one, ſo as to project between his eyes, the child rather than turn his head to look at oblique objects, began to view them with that eye which was next to them; the father of the child dying, the cure was neglected for ſix years, and though the habit was ſo confirmed as to leave little room for a cure, the ſame phyſician being called, he again attempted to remove the deformity by a ſimilar contrivance.

A gno-

A gnomon of thin braſs was made to ſtand over his noſe, with a half circle of the ſame metal to go round his temples; they were covered with black ſilk, and fixed by means of a buckle behind his head, and a croſs piece over the crown of the head; this gnomon was worn without inconvenience, and projected before the noſe about two inches and a half. By the uſe of this he ſoon found it leſs inconvenient, to view all oblique objects with the eye next them, inſtead of the eye oppoſite to them.

After this habit was weakened by a week's uſe of the gnomon, two bits of wood, about the ſize of a gooſe quill, were blacked, all but a quarter of an inch at their ſummit. Theſe were frequently preſented to him to look at, one being held on one ſide of the extremity of his black gnomon, and the other on the other ſide of it. As he viewed theſe, they were gradually brought forward beyond the gnomon, and then one was concealed behind the other; by theſe means, in another week he could bend both his eyes on the ſame object, for half a minute together, and by continuing the uſe of the ſame apparatus, he was in a fair way of recovery, when the paper was written for the tranſaction.

FINIS.

A CATALOGUE OF Mathematical, Optical, and Philoſophical INSTRUMENTS,

MADE AND SOLD BY

GEORGE ADAMS,

Mathematical Inſtrument Maker to His Majeſty, and Optician to His Royal Highneſs the Prince of Wales,

No. 60, FLEET-STREET, LONDON.

Optical Inſtruments.

	£.	s.	d.
The beſt double-jointed ſilver ſpectacles, with glaſſes	1	1	0
The beſt ditto, with Brazil pebbles	1	16	0
Single joint ſilver ſpectacles, with glaſſes	0	15	0
Ditto, with Brazil pebbles	1	10	0
Double-joint ſteel ditto, with glaſſes	0	7	6
Beſt ſingle-joint ſpectacles	0	5	0
Ditto, inferior frames, from 2s. 6d. to	0	3	0
Noſe ſpectacles mounted in ſilver	0	7	6
Ditto in tortoiſe ſhell and ſilver	0	4	0
Ditto in horn and ſteel	0	1	0
Spectacles for couched eyes			

Spectacles

	£.	s.	d.
Spectacles with ſhades			
Concave glaſſes in horn boxes, for ſhort-ſighted eyes			
Ditto, mounted in tortoiſeſhell and ſilver, pearl and ſilver, in various manners, and at different prices			
Reading glaſſes, from 2s. 6d. to —	2	2	0
Opera glaſſes, from 10s. 6d. to —	2	2	0
Ditto on an improved conſtruction, 1l. 7s. and	1	11	6
Ditto to be uſed at ſea by night —	1	11	6
Diagonal operas of a new conſtruction —	1	1	0
Teleſcopes of various lengths, ſizes, and prices			
Acromatic teleſcopes, portable and convenient for the pocket, the ſliding tubes are of braſs, and therefore not ſubject to the inconveniencies of thoſe that are made with vellum drawers, from 1l. 11s. 6d. to — —	8	8	0
Teleſcopes to be uſed at ſea by night			
Acromatic perſpective glaſſes for the pocket, from 10s. 6d. to — —	2	12	6
An optical vade mecum, or portable acromatic teleſcope and microſcope, from 3l. 13s. 6d. to	4	14	6
A thirty-inch acromatic teleſcope, with different eye-pieces for terreſtrial and celeſtial objects; this is one of the moſt pleaſant teleſcopes that is made for general purpoſes, from 8l. 8s. to	11	11	0
An acromatic teleſcope, about three feet and an half long, with different eye-pieces —	18	18	0
A three-feet reflecting teleſcope, with four magnifying powers, with rack work —	36	15	0
A ditto, two feet long, with ditto —	21	0	0
A two feet reflecting teleſcope, with two powers	12	12	0
An eighteen-inch ditto —	8	8	0
A twelve-inch ditto — —	5	5	0
Adams's LUCERNAL MICROSCOPE, for opake and tranſparent objects; it does not fatigue the eye, is in all caſes a proper ſubſtitute for the ſolar microſcope, and on many occaſions ſuperior to it — —	21	0	0
A ſmall double-reflecting microſcope —	2	12	6
A larger ditto — —	3	13	6
An improved univerſal double microſcope	6	6	0
Ditto fitted up in a different form, from 8l. 8s. to	14	14	0
Ellis's aquatic microſcope —	2	2	0
Ditto with an adjuſting ſcrew —	2	12	6
Withering's and other botanical microſcopes, from 10s. 6d. to — —	3	3	0

Small

	£.	s.	d.
Small pocket microfcopes, from 6s. to —	3	13	6
Solar microfcopes —	5	6	0
Ditto — —	6	6	0
Solar microfcopes for opake and tranfparent objects, from 1l. 16s. to —	21	0	0
A microfcope and lanthorn to imitate the folar microfcope			
Curious collections of objects for the microfcope, either opake or tranfparent			
Collections of falts, properly prepared for the microfcope			
Magnifying glaffes for botanical, anatomical, and other purpofes, from 2s. to —	1	11	6
Small magic lanthorns, with twelve fmall glafs fliders, from 10s. 6d. to —	1	1	0
Small magic lanthorns, with the fliders better painted			
Large ditto, from 1l. 5s. to —	1	11	6
Optical machines for viewing perfpective prints, from 18s. to — —	1	16	0
Scioptric balls — — —	0	10	6
Small camera obfcuras, from 10s. 6d. to	3	3	0
Book and pyramidical camera obfcuras, from 3l. 3s. to — —	7	7	0
An artificial eye for illuftrating the principles of vifion			
Prifms, mounted in various manners			
Concave and convex mirrors, from 7s. 6d. to	18	18	0
Cylindrical ditto, from 1l. 1s. to —	13	13	0

Geographical and Aftronomical Inftruments.

PRICES OF GLOBES.

			£.	s.	d.
28	inches diameter,	mounted in mahogany frames	52	10	0
28	ditto	frames carved and ornamented			
18	ditto	mounted in the common manner	6	6	0
18	ditto	mounted in the common manner in mahogany frames —	8	8	0
18	ditto	mounted in the best manner, in ftained frames — —	10	10	0
18	ditto	mounted in the beft manner, in mahogany frames —	12	12	0

	£.	s.	d.
18 inches diameter mounted in the best manner, in carved frames —— ——	16	16	
16 ditto mounted in the common manner	6	6	0
12 ditto mounted in the common manner	3	3	0
12 ditto mounted in the common manner, in mahogany frames ——	4	4	0
12 ditto mounted in the best manner, in stained frames —— ——	5	15	6
12 ditto mounted in the best manner, in mahogany frames ——	7	7	0
9 ditto mounted in the common manner	2	2	0
9 ditto mounted in the best manner	4	4	0
6 ditto mounted in the best manner	3	3	0
3 ditto mounted in the best manner	1	11	6
3 inches diameter, for the pocket —	0	10	6
An armillary dialling sphere ——	40	0	0
An armillary sphere, shewing at one view the real and apparent motion of the heavens	31	10	0
An armillary sphere, with a planetarium within it	31	10	0
Plain armillary spheres			
A manual planetarium and tellurian —	3	13	6
A new instrument for illustrating the phænomena of the seasons —— ——	4	10	0
A ditto for illustrating the phases of the moon, and the causes of eclipses ——	4	10	0
A manual planetarium —— ——	2	2	0
(The three last-mentioned instruments are those represented in plates V. XV. and XVI. of my Astronomical Essays)			
A planetarium with wheel-work, by which the order and motion of the planets, their situation with respect to the earth at different times, and the reason of their appearing to be sometimes stationary, and to move at other times in contrary directions, are rendered obvious to the eye	7	17	6
A tellurian and lunarium for illustrating the phænomena of the earth and moon, and forming a proper companion for the former			
(The tellurian and lunarium may be combined together or separate)			
A correct and elegant planetarium, lunarium, and tellurian, (see plate XIX. of my Astronomical Essays) —— ——	18	18	0
Ditto with the diurnal motion to the earth	24	0	0
The most complete planetarium, tellurian, and lunarium, plates XVII. and XVIII.	36	15	0

Orreries,

Orreries, from 18l. 18s. to	1000	0	0
A small quadrant, with an horizontal and vertical motion, for the instruction and amusement of young people	0	16	0
A ditto framed in brass, more accurately made and graduated	2	12	6
A small equatorial, being at once an accurate universal dial, and a portable observatory; with it a great number of curious and interesting problems may be solved, and any person soon rendered master of the elements of practical astronomy	8	8	0
Ditto on a larger scale, with a telescope, and more adjustments	26	5	0
Complete equatorial instruments, from 50gs. to	500	0	0
Transit instruments, astronomical quadrants, circular instruments, according to their sizes, the variety and accuracy of their adjustments.			

Mathematical Instruments, for Geometry, Drawing, &c.

Plain compasses for measuring lines, from 1s. to	0	5	0
Drawing compasses with moveable points, from 5s. 6d. to	3	3	0
Drawing pens, from 1s. to	0	5	0
Bow compasses for describing small circles, from 3s. to	0	5	0
Hair compasses for taking extents with accuracy	0	7	6
Beam compasses for describing large circles, laying down divisions, &c.			
Triangular compasses for transferring three points at once from any plan or drawing, from 18s. to	1	1	0
Proportionable compasses for diminishing plans, or drawing in any assigned proportions	1	11	6
Elliptical compasses with friction rollers, for drawing ellipses	4	4	0
Elliptical compasses on a different construction, answering at the same time the purposes of beam and calliper compasses	4	4	0
Spiral compasses for describing spirals, answering also as beam and elliptical compasses, from 6l. 6s. to	31	11	0
Parallel rules of various constructions			

	£.	s.	d.
A new-invented parallel rule, which for facility in application, and accuracy, exceeds any other kind, from 8s. 6d. to ———	1	1	0
Ditto with a protractor			
An inſtrument for drawing lines inclined in a given angle to each other, though the angular point is at an immenſe diſtance, a rule exceedingly uſeful in perſpective			
Various inſtruments for the purpoſe of dividing lines, or transferring diviſions on paper			
A cyclograph, or an inſtrument by which circles may be deſcribed, from 4 or 6 inches radius to one as large as the orbit of the Georgium Sidus	6	6	0
Plain ſcales and ſectors of different ſizes			
Square protractors, ſemicircular and circular			
Pocket caſes of drawing inſtruments, from 7s. 6d. to	5	15	6
Magazine, or complete collection of drawing inſtruments, at 11l. 11s. at 17l. 17s. and from thence to —— ——	50	0	0
Perſpective compaſſes for aſcertaining the relative proportion of objects ———	0	18	0
A new invented inſtrument for taking views, &c. which will facilitate the operations of the artiſt, and greatly aſſiſt beginners ———	3	3	0
A ditto for drawing on an horizontal plane	5	5	0
Pantographers for copying, reducing, and enlarging drawings, from 2l. 12s. 6d. to ——	6	6	0

Surveying Inſtruments.

	£.	s.	d.
Caſes of drawing inſtruments.—Parallel rules.—Plotting ſcales.—Sets of plotting ſcales.—A new-invented parallel rule, with plotting ſcales.—A parallel rule and protractor			
A plotting ſcale, in form of a beam compaſs			
Protractors for laying down angles			
Ditto with a nonius and moveable limb —	2	12	6
Ditto rendered more accurate, as the limb is made to move with a tooth and pinion ——	4	14	6
Meaſuring wheels —— ——	6	16	6
Pedometers for meaſuring a given diſtance in walking			
Meaſuring chains of 50 and 100 feet			

	£.	s.	d.
Gunter's chain	0	7	6
Tape boxes, according to the length			
Surveying croſs or ſquare	1	11	6
Plain tables, with an index and ſights; by theſe the plan is taken on the ſpot, and does not require a future protraction	3	13	6
Beighton's improved plain table, with an index of a peculiar make; in this inſtrument the line of ſight is always over the center of the table, the ſtation lines are alſo drawn parallel to thoſe meaſured on the ground	14	14	0
Theodolets, or inſtruments for meaſuring angles, diſtances, &c. are made in various ways, ſome being more ſimple and portable, others more accurate, and with a greater number of adjuſtments			
Theodolets, with four plain ſights, and a compaſs box, from 5l. 5s. to	5	15	6
A ſmall theodolet, with teleſcopic ſights and vertical arch	9	9	0
An improved ſmall theodolet with rack motions			
A larger ditto, in which the limb of the theodolet is made to ſerve occaſionally the purpoſe of a protractor	14	14	0
A ditto of the ſame ſize, on a different conſtruction, the vertical arch being fixed to a long axis; the limb does not ſerve for a protractor	14	14	0
A larger ditto, like the preceding, only moving with rack-work	21	0	0
The lateſt improved theodolet, with double teleſcope, and every requiſite adjuſtment			
Circumferenters, the principal inſtrument uſed in America, from 2l. 2s. to	4	14	6
An improved circumferenter, ſo contrived, that the operator need not reſt the truth of his work entirely on the needle; it may be alſo uſed to take altitudes			
Air or ſpirit levels with teleſcopic ſights, from 4l. 14s. 6d. to	12	12	0
Air or ſpirit levels with plain ſights	1	11	6
Station ſtaves with ſliding vanes for levelling	1	16	0
A ſmall ſurveying compaſs, with ſights, a nonius diviſion, and three-legged ſtaff	4	14	6
A ſmall ſurveying compaſs and ſingle ſtick	2	2	0

(The two foregoing inſtruments are portable and light, and may be put with eaſe in the pocket)

	£.	s.	d.
Miners compaſſes, uſed for carrying on works under-ground, from 10s. 6d. to —	1	1	0
Ditto with a ſmall teleſcope fixed to one ſide	1	11	6
Green's teleſcope and tangent board, for meaſuring diſtances at one ſtation: (it is obvious, that on the meaſuring of a ſtrait line with accuracy, the whole buſineſs of ſurveying depends; Mr. Green's method is certainly more expeditious than any other, and is not liable to objections which may be made to them)			
Optical ſquare, a ſmall inſtrument for ſurveying by right angles; it requires no ſtaff, and may be eaſily corrected or adjuſted —	1	16	0
An optical inſtrument for determining with accuracy when objects are in a ſtrait line —	1	7	0

Inſtruments for Electricity.

A ſmall electrical machine, with a ſelect apparatus	8	8	0
An electrical machine and medical apparatus in a box; the machine is mounted in a plain but ſtrong manner, and ſo as to act with power; the apparatus is the moſt convenient and ſimple hitherto contrived for medico-electrical purpoſes	6	16	6
Ditto with an additional apparatus lately contrived for more eaſily giving partial ſhocks —	7	17	6
Improved electrical machines, from 3l. 13s. 6d. to	40	0	0
Electrical batteries, from 2l. 12s. 6d. to			
Electrical jars of different ſizes			
Electrical jars with an electrometer affixed to them	0	18	0
Medical bottles, with a tube for qualifying the ſhock — — —	0	7	6
Ditto mounted with a diſcharging rod, and an electrometer, on an improved plan, for giving the electric ſhock — —	1	1	0
Directors with glaſs handles for medical purpoſes	0	10	6
Jointed diſchargers with glaſs handles —	0	10	6
Plain diſcharging rods — —	0	3	0
An univerſal diſcharger and preſs —	1	11	6
Kinnerſly's electrical thermometer —	1	1	0
Quadrant electrometer — —	0	10	6
Cavallo's atmoſpheric electrometer, from 15s. to	1	1	0
Ditto with additions by De Sauſſure —	1	11	6

Bennet's

	£.	s.	d.
Bennet's gold leaf electrometer	0	18	0
An apparatus for making Canton's and Wilſon's experiments on electric attraction, &c.			
Compound apparatus, fig. 49, plate III. of my Eſſays on Electricity; by this apparatus a great number of neat and ſatisfactory experiments may be performed	3	3	0
Ditto without the exhauſted flaſk and conductor	1	11	6
Leyden vacuum	0	10	6
Luminous conductors	1	1	0
Spiral tubes, from 4s. 6d. to	0	10	6
Coloured ſpirals	0	9	0
Sets of ſpirals, ſee plate V. fig. 98, of my Eſſays on Electricity	1	11	6
Luminous words, from 10s. 6d. to	1	11	6
Spotted bottle	0	9	0
Belted bottle, plate III. fig. 46	1	1	0
Double bottle, a pleaſing and uſeful part of an electrical apparatus, to gain a clear idea of the Frankiinian theory	0	18	0
Plates and ſtand for dancing images, pith images, and pith balls			
An artificial ſpider			
A ſmall head with hair	0	7	6
An electrical piſtol for inflammable air	0	7	6
Ditto mounted in ſets			
A ſet of paper working models, to be put in motion by the electric fluid	2	12	6
An electrical cannon for gunpowder			
Thunder houſe	0	6	6
A thunder houſe with a drawer	0	8	6
A powder houſe, fig. 89, plate V.	0	16	0
A pyramid, fig. 90, plate V.	0	15	0
Nicholſon's revolving doubler	2	8	0
A bone ball and a ball of box wood fitted on braſs wires			
Electric flyer and points			
A plain ſet of bells, fig. 17, plate II.	0	9	0
Five bells mounted on a ſtand, fig. 18, plate II.	0	18	0
A ſet of muſical bells, fig. 19, plate II.	1	7	0
Magic picture	0	10	6
Electrical ſtools, from 8s. 6d. to			
An electrophorus, from 10s. 6d. to			

Apparatus for Experiments on Magnetiſm.

	£.	s.	d.
An apparatus for explaining the principal phænomena of magnetiſm, from 3l. 3s. to —	15	15	0
Magnets			
Small compound magnets			
Horſeſhoe magnets			
Compound ditto, from 15s. to —	21	0	0
Dipping needles from 12l. 12s. to —	31	10	0
Variation compaſſes, 2l. 12s. 6d. to —	21	0	0

Inſtruments for Experiments on Pneumatics.

A ſmall ſingle-barrel air-pump —	2	12	6
A ſmall double-barrel ditto —	4	14	6
A larger ditto — —	6	16	6
A table air pump —	10	10	0
The American double barrelled air pump, the lateſt improvement on this inſtrument, in which the air receives no impediment from the action of valves or cocks, exceeding Smeaton's in accuracy and ſimplicity, and far ſuperior in both reſpects to ſeveral later contrivances			
A condenſing engine; this may be, if deſired, combined with the former, but the rational and practical experimentaliſt will find many advantages in having them detached from one another			

Apparatus for an Air Pump.

The madgeburg hemiſpheres, from 12s. to	1	11	6
A flat plate and collar of leathers for placing on open receivers — —	0	15	6

Guinea

	£.	s.	d.
Guinea and feather apparatus, for experiments on the reſiſtance of the air, from 18s. to —	1	11	6
A ſet of mills for ditto —	1	11	6
A ditto on a better conſtruction —	4	4	0
Bell apparatus, for ſhewing that a vacuum does not communicate ſound —	0	5	6
Ditto on a better conſtruction			
Ditto with wheel-work, by which the bell may be put in motion or ſtopped at pleaſure —	3	13	6
A new apparatus for ſtriking flint and ſteel in vacuo			
An apparatus for firing gunpowder in vacuo			
A copper bottle, beam and ſtand, for weighing of air	2	16	0
A box bladder and lead weights, to ſhew the elaſtic power of the air — —	0	15	6
Ditto on an improved plan —	0	18	0
A model of a pump, illuſtrating at the ſame time the nature of pumps, and proving that there is no ſuch thing as ſuction —	1	5	0
A ſmall receiver and plate, which clearly evinces that receivers are kept on the pump by preſſure, not ſuction — —	0	12	0
A filtering cup — —	0	5	6
A plate and piece of wood —	0	4	6
(The two laſt articles are for ſhewing the poroſity of vegetables)			
The torricellian experiment			
Fountain in vacuo — —	0	5	6
Ditto on a different conſtruction —	0	18	0
Lungs glaſs — —	0	5	6
Ditto on a different conſtruction			
A ſingle transferer plate and pipe for a fountain	0	15	6

Inſtruments for Navigation.

Caſes of inſtruments, and teleſcopes of different kinds, ſizes, and prices			
Night teleſcopes, from 1l. 11s. 6d. to —	[illegible]	[illegible]	[illegible]
Opera glaſs for the ſame purpoſe —	1	11	6
A teleſcope with an eye-glaſs micrometer, for determining the diſtance of a ſhip at ſea			

Instruments for Experiments in Hydrostatics and Hydraulics.

	£.	s.	d
Hydrostatic ballances, from 2l. 2s. to —	10	10	0
Nicholson's improved hydrometers, for ascertaining the specific gravity of bodies			
Ditto for examining of coin			
A concise apparatus for experiments on hydrostatics	21	10	0
An apparatus for shewing that fluids have weight			
Ditto for shewing that the particles of fluids exercise their pressure independently one of the other			
Ditto to shew that fluids press in every direction			
Ditto to demonstrate the lateral pressure of fluids			
Ditto to shew that, *cæteris paribus*, the pressure of fluids is as their perpendicular height			
The hydrostatic paradox			
The hydrostatic bellows			
Apparatus for illustrating the laws of pressure and equilibrium between heterogeneous fluids			
Ditto for illustrating the actions of fluids upon bodies immersed in them			
An apparatus for experiments on spouting fluids			
Hydrometers for proving spirits, from 1l. 11s. 6d. to	4	14	6
An apparatus for making experiments on capillary tubes			
The model of the diving bell			
A glass model of the lifting pump			
A ditto of the lifting and forcing pump			
Hiero's fountain in copper japanned			
Ditto double			
Fountain of command			
A japanned copper fountain to act by condensed air with a variety of jets			
Apparatus for experiments on syphons.			